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NATIONAL SURVEY OF THE ODOR PROBLEM

Phase I

of a Study of the Social and Economic Impact of Odors

Prepared for the
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION
by
COPLEY INTERNATIONAL CORPORATION

COLOR ILLUSTRATIONS REPRODUCED
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The intent was the generation of information relative to the basic definition, identification, and assessment of the national odor problem. Three factors - odor producing potential of industrial odorant sources, atmospheric vulnerability, and size of population - were developed separately and then combined for an indication of the odor problem potential of each three digit postal zip code area in the nation. Local air pollution control agencies were surveyed to identify areas where they believe that significant odor problems exist. Within the principal cities of each of seven representative metropolitan areas, two-day technical field investigations and public opinion surveys were conducted. Sensory evaluations of odor were also performed in Philadelphia, Pennsylvania. Odor problem potential exists in most metropolitan areas in the United States. But, primarily because of meteorological factors, the probability of encountering odor problems is greatest in the Appalachian and California Coastal metropolitan areas. A large number of residents - perhaps as many as 25 million - perceive odors as problems and desire some form of abatement. The results of the mail survey and personal interviews of local air pollution control agencies indicated that when concentrations of air pollutants can be related to amounts of property damage and/or ill health, abatement criteria (e.g., minimum levels of →

(continued on back of page)

17. Key Words and Document Analysis. (a). Descriptors

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emissions) can be established and enforced. However, in cases of air pollutants causing only odors, such relationships are generally non-existent. Consequently, odor abatement criteria, if any, are typically based on number of complaints and inadequately backed by nuisance laws.

NATIONAL SURVEY OF THE ODOR PROBLEM
List of Errata

TEXT

Page No.	Location	Description
81	Figure 1, Legend	**Second and third boxes are reversed.** **Description should be:** ▩ **Population of from 150,000 to 327,000** ▨ **Population of from 56,000 to 149,000**
83	Figure 2, Legend	**Second and third boxes are reversed.** **Description should be:** ■ **Weighted value of from 246 to 675** ■ **Weighted value of from 75 to 245**
93	Line 4	**"Pump" should be "pulp."**
97	Line 15	**"Affect" should be "effect."**
136		**Should be Page No. 144.**
137-144		**Should be Page Nos. 136-143.**
153	Figure 14	**Arrow at left center of page should be labeled, "To Rendering Plant."**
166	Table IV	**"Kansas City" should be 175 residents and 25 businessmen (Test Area), 176 residents and 25 businessmen (Control Area).** **"Buffalo" should be 170 residents and 25 businessmen (Test Area), 180 residents and 25 businessmen (Control Area).** **"Tampa" should be 175 residents and 25 businessmen (Test Area), 175 residents and 26 businessmen (Control Area).**

List of Errata (cont'd)

Page No.	Location	Description
166	Table IV (cont'd)	"San Francisco" should be 177 residents and 25 businessmen (Test Area), 160 residents and 22 businessmen (Control Area).
166	Table V	"Kansas City" should be 89 men and 86 women (Test Area), 87 men and 89 women (Control Area). "Buffalo" should be 86 men and 84 women (Test Area), 86 men and 94 women (Control Area).
171	Table VI	"High taxes" should be 62% (Test Area) and 58% (Control Area).
175	Table VIII	"Noticeable odors" should be 82% (Test Area) and 67% (Control Area). "Irritation of the eyes" should be 69% (Test Area) and 67% (Control Area).
194	Note 2, formula	Replace "r" with "s" above second summation sign.

APPENDIX

Page No.	Location	Description
Title	Center of page	Contract number should be CPA 22-69-50.
A-9	At the end of Table A-III	Notes to Table A-III should be: * Selenium compounds ** Acid fumes *** Caustic units Source to Table A-III should be: Arthur C. Stern (ed.). Air Pollution, Vol. III (2nd ed.; New York: Academic Press, 1968).

List of Errata (cont'd)

Page No.	Location	Description
	Appendix G through M, the results of each survey question	Except for base numbers, each number listed under the headings "Test," "Control," and "Total" is a percentage of the number of responses obtained for a given category to the total number of responses obtained for all categories. Base numbers ("Bases") indicate the total number of responses obtained for all categories.
G-4 and G-5	Q4B and Q4C	Bases should be 226 (Test Area), 219 (Control Area), and 445 (Total).
G-6	Q6B	Bases should be 394 (Test Area), 351 (Control Area), and 745 (Total).
G-10	Q8G	Bases should be 1,000 (Test Area), 811 (Control Area), and 1,811 (Total).
G-13	Q14B, line 1	"Reduces" should be "reduced."
I-30	Q14C	Bases should be 7 professional/technical (Test Area) and 2 professional/technical (Control Area) Occupation categories (column headings) should be "Professional/Technical," "Managers/Self-Employed," "Clerical/Sales," "Skilled/Service," "Labor," "Student," "Retired," "Housewife," "Unemployed," and "Refused."
M-1, M-2	Q1, Q2A	Bases for "Buffalo" should be 170 (Test Area) and 180 (Control Area).
M-5 through M-12	Q3	
M-13, M-17	Q4A, Q5	
M-19, M-22	Q6A, Q7A	
M-25, M-31	Q8, Q9A	
M-34, M-43	Q10, Q16A	
M-45, M-48	Q17A, Q18A	
M-50	Q18B	
M-52 through M-57	Q19 through Q23	

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Contributions were made to this report by

ENGINEERING-SCIENCE, INC.

January, 1970

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The work upon which this report is based was performed pursuant to Contract No. CPA 22-69-50 with the National Air Pollution Control Administration, Public Health Service, Department of Health, Education and Welfare.

CONTRIBUTIONS

The overall responsibility of this study was undertaken by Mr. Stuart H. Neffeler, Vice President, Copley International Corporation. Others who contributed to the success of this study included:

Dr. Amos Turk, Project Consultant and Professor, City College of the City University of New York.

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CHAPTER I

INTRODUCTION

There has been an increasing nationwide concern over the general problem of air pollution in recent years, culminating in the passage of the Air Quality Act of 1967 by the United States Congress. Within the provisions of this act, the National Air Pollution Control Administration (NAPCA), an agency of the Public Health Service, Department of Health, Education and Welfare, was assigned the task of developing air quality criteria to serve as guidelines for the local regulatory control of air pollutants. Primary emphasis in the development of these criteria was placed on the documentation of technology for the abatement and control of pollutant emissions and on the assessment of the social, economic, and general environmental effects of pollutants.

In accordance with these plans, NAPCA engaged Copley International Corporation (CIC) as prime contractor, with Engineering-Science, Inc. (ESI), as subcontractor, to conduct a study of the social and economic impact of odors. Phase I of this study was directed toward the generation of information relative to the basic definition, identification, and assessment of the national odor problem. Further research, during Phase II, is to be oriented toward the development of a method of assessing the social and economic impact of an odor problem on a typical community in the United States.

Copley International Corporation was primarily concerned with surveys of all local air pollution control agencies in the nation and public opinion in seven metropolitan areas. Engineering-Science, Inc., was primarily responsible for a comparison of analytical techniques for odor evaluation. Both organizations contributed information leading to the identification of odor problem areas throughout the United States. A statement of the objectives and methodology and a summary of the principal findings of this study are presented in the following sections of this chapter.

OBJECTIVES AND METHODOLOGY

The overall objective of Phase I was an assessment of the national odor problem based on the projections of the results of investigations in a selected sample of odor problem areas. Tasks leading to this objective included:

- The identification and description of major odorants and odorant sources.

- A determination of the odor producing potential and the location of groupings of industrial odorant sources.
- A determination of the effects of the natural environment on odor problems and the identification of odorant supporting atmospheric regions.
- The location of concentrations of population.
- A survey of local air pollution control agencies.
- The selection of seven metropolitan areas for investigations of actual odor problems.
- A series of technical field investigations and sensory evaluation of odor studies.
- A series of public opinion surveys of residents and businessmen.
- A formulation of recommendations for the development of a method to assess the social and economic impact of odors (for use in Phase II of the study).

In order to ultimately assess the national odor problem, it was necessary to identify and evaluate the odor problem potential of areas throughout the United States. In doing so, three basic factors — odor producing potential of industrial odorant sources, atmospheric vulnerability, and size of population — were developed separately and then combined for an indication of the odor problem potential of each three-digit postal zip code area in the nation. Each of these factors represented a condition (or conditions) defined as necessary for the presence of an odor problem in an area:

- Industrial odor producing potential was intended to represent the number of industrial plants weighted by the aggregate effects of odors generated and the relative size of these plants.
- Atmospheric vulnerability was intended to represent the major causes of impaired atmospheric dilution capacity.
- Size of population was intended to represent the potential extent of odor problems.

The primary objective of the survey of local air pollution control agencies was to identify areas in the United States where agency officials believe that significant odor problems exist. Based on responses received from agency officials and knowledge of the fifty metropolitan areas having the largest concentrations of persons and highest industrial odor producing potential, seven metropolitan areas were selected as representative potential odor problem areas in which actual odor problems were to be investigated.

Within the principal cities of each of these metropolitan areas, a technical field program and public opinion surveys were conducted. The technical field program included two-day field investigations. In addition, sensory evaluation of odor studies were performed in Philadelphia, Pennsylvania.

The objectives of the two-day field investigations were to interview air quality control agency officials in each of the seven metropolitan areas for the purpose of determining the manner in which odor problem situations are evaluated and documented. An additional objective was to identify actual odor problem areas, the extent of the areas affected, and the types of emission causing concern. A public opinion survey was then conducted in at least one of these areas in each of the cities investigated.

The objectives of the Philadelphia studies were to apply direct sensory evaluation techniques to the documentation of odorant emissions from two sources, compare the responsiveness of the scentometer with odor panelists, and develop a capability for sensory evaluation techniques for use in Phase II.

The public opinion surveys were conducted as an exploratory approach to determine the extent to which odors constitute an influence on the lives of people living and working in actual odor problem areas. The objectives were to determine the degree of awareness of the public to odors, whether differences of opinion regarding odors exist between people living in odor problem areas and people living in relatively odor-free areas, if people feel they have suffered socially or economically due to the presence of odors, and the degree of interest the public may have in odor abatement.

Because of the exploratory nature of the survey (and, indeed, the study as a whole), a variety of questions and question approaches were used with the expectation that some would generate usable information while others might not allow for valid discrimination between the variables. The usable results were to be projected to the nation as a whole.

SUMMARY OF THE PRINCIPAL FINDINGS

The principal findings of this study were drawn from the results of the technical field program and the surveys of local air pollution control agencies and public opinion. These findings are summarized below.

Results of the Survey of Local Air Pollution Control Agencies

The responses received from the mail survey of 184 local air pollution control agencies in the United States indicated that odor problems exist in many cities and counties throughout the nation. It was further indicated that the odor problems, in general, affected a very large number of people.

Four categories of sources were responsible for almost half of the odor problems reported. These categories were: rendering/meat packing/slaughterhouses; chemical/plastic plants; sanitary land fill/dumps/open burning/incinerators; petroleum and natural gas refining/asphalt production. In contrast, the four categories reported to have the highest monthly average number of complaints were: sanitary land fill/dumps/open burning/incinerators; fisheries and fish processing; rubber/tires production; coffee roasting/spices. The responding agencies viewed chemical/plastic plants as the most serious odor sources and pulp/kraft/wood mills as the sources of the fastest growing problems.

The identification and assessment of odor problems was accomplished by a large number of the reporting agencies using the human nose, common sense, and number of complaints as criteria. An equally large number of agencies reported that there are many inadequacies in current methods of assessment and expressed a need for assistance in establishing criteria.

Over 70 percent of the responding agencies take some form of abatement action. One of the most popular forms of abatement appears to be persuasion.

In addition to the mail survey, personal interviews were held with agency representatives in each of the seven metropolitan areas investigated. The following observations are from those interviews.

The most frequently used legislation relating to odor abatement is found in local and state nuisance ordinances. Due to staff limitations in air pollution control agencies as well as the general requirement that a considerable number of persons perceive an odor situation as a nuisance, nuisance laws have been ineffective tools in abating odors. To the extent this study could determine, none of the metropolitan areas investigated had a record of substantial fine or other judicial penalty levied against an odor pollution violator.

Results of the Field Technical Program

The following results were obtained from the two-day field investigations and the sensory evaluation of odors studies.

The scentometer, a vapor dilution technique device, was found to be a utilitarian and effective tool for odor problem identification at a point in time and space.

Using the scentometer in each of the metropolitan areas visited, refinery installations and chemical facilities were found to be the most significant sources of odor emissions in terms of areal extent.

The sensory evaluation technique for atmospheric odor measurement provided definitive descriptions of the areal extent and relative magnitude of odor emissions. This technique should have substantive application in those special circumstances where legal liability or compliance questions require explicit documentation of an odor emission.

Results of the Public Opinion Survey

The findings of the public opinion survey indicated that over 60 percent of the residents and businessmen interviewed in the survey test areas perceived air pollution as a problem. In defining air pollution, over 80 percent of these respondents included "noticeable odors."

Residents and businessmen expressed an awareness of odors not only in the survey test areas, but also in the similar, but relatively odor-free, control areas. In general, however, businessmen were not as concerned as residents about the presence of odors.

The type of resident found in both the test and control areas in this study can perhaps best be characterized as lower-middle class. He tended to be blue collar, middle-aged or older, below average in education and income, and with family size lower than average.

Awareness of air pollution problems tended to rise with increases in the resident's educational attainment, income, occupational level, and youth. Young respondents were apt to consider noticeable odors as a basic element of air pollution to a slightly greater degree than did older residents. However, the vast majority of all age groups held this view.

Although awareness of odors was expressed in test and control areas, test area residents were more aware of odors, able to identify odor sources, and discontent with the situation. Almost 20 percent of the test area residents felt that odor pollution in their areas of their cities was continuously serious. Only about 5 percent of control area residents held the same view. Test area residents stated that industries were the principal sources of odor in their areas, while control area residents believed motor vehicles to be the main source. Almost 74 percent of test area residents who stated odor pollution was at least occasionally serious felt that more money should be spent to control odor pollution in their areas. About 59 percent of control area residents felt that more money should be spent for this purpose.

Assessment of the National Odor Problem

The results of the public opinion survey indicated an awareness of odors among residents and businessmen in test and control areas. Difficulty arises in attempting to extrapolate the awareness level of perception to the problem level. In this study, the differentiation between these levels was attempted through careful development of the public opinion survey questionnaires. It was planned that the responses to the questionnaires would provide the necessary data for an assessment of the extent of odor problems in the survey areas.

A further difficulty was encountered in attempting to project the extent of odor problems beyond the survey areas. To assist in overcoming this problem, the following assumptions were formulated:

(1) The seven metropolitan areas investigated in this study are generally representative of most metropolitan areas in the United States. (Selection criteria are discussed in Chapter VII.)

(2) Two-thirds of the estimated 137 million persons in the 155 metropolitan areas of the nation are male and female adults in households (residents).

(3) Only 10 percent of these residents live in actual odor problem areas (similar to the public opinion survey test areas) and that 90 percent live in relatively odor-free areas (similar to the survey control areas).

From this, it is projected that 25 million residents in the United States could be expected to state that air pollution is a problem and that odors are a major element. Based on these assumptions, further projections of the extent of odor problems can be made:

(1) About one and one-half million residents would voluntarily state that odors are a disadvantage to living in their areas of their cities.

(2) Almost five million residents would admit that odors bothered them very much.

(3) More than five and one-half million residents would state that odors are a continuously serious problem.

(4) About three million residents would feel that odor pollution has reduced the value of their home property.

(5) Almost five million residents would have seriously considered moving away from their areas because of odor pollution.

(6) Only one-half million residents would have requested some authority or agency to take action concerning air polltuion. The number of residents that would have requested action concerning odor problems would be a small fraction of this.

On the basis of these projections, a large number of residents perceive odors as a problem. Yet only a small percentage of these residents are motivated to seek recourse. The reasons for this apparent apathy cannot be inferred from the public opinion survey findings. Instead, additional study of attitudes is required to develop meaningful conclusions.

CHAPTER II

THE NATURE OF ODORS, MAJOR ODORANTS AND ODORANT SOURCES

As a preface to the method of locating and assessing potential odor problem areas across the United States, this chapter begins with a discussion of the nature of odors. Particular emphasis is given to the inherent odor characteristics — intensity, quality, acceptability, and pervasiveness.

The remaining section of the chapter describes the development of a set of aggregate odor characteristic coefficients, each of which is to represent an aggregation of the perceptive characteristics of odorants attributable to a specific source. Engineering-Science, Inc., developed these coefficients by first identifying major sources of odorant emissions and the physico-chemical nature of the emissions from these sources, by classifying the sources by Standard Industrial Classifications (SIC), and then by subjectively assigning a quartile ranking to the sources based on the characteristics of the odorants emitted.

THE NATURE OF ODORS

Odors can be classified in two categories: source and ambient. Source odors are those existing at the point of origin or at their point of exit to the general atmosphere, and ambient odors are those existing in the general atmosphere.[1] Odors can be confined or unconfined as to odor source. Confined sources can generally be characterized in terms of volumetric rate of discharge, temperature, moisture content, location, elevation, area, stack height, and state of aggregation (gas, mist, etc., including particle size distribution, etc.).[2] Typical confined sources include stacks and fume vents. Unconfined sources consist of large sources such as sewage treatment plants and stockyards where the areal extent of the source precludes its confinement.

Ambient odors are unconfined in the source context. However, a confinement may exist in the sense that the atmospheric volume into which the odor is emitted may be limited by meteorological considerations such as wind speed, mean mixing depth, humidity, etc., and by topographical constraints to the extent that the level of odorant may remain steady or even increase rather than decrease.

Odors can be characterized by intensity, quality, acceptability, and pervasiveness. Odor intensity is defined as the numerical or verbal indication of the strength of an odor. Odor quality is the verbal description of an odor, accomplished within the vocabulary capabilities of the individual and normally expressed by comparison

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with common odors. Acceptability is an absolute acceptance/rejection of the odor on the basis of intensity and/or quality. Pervasiveness is the ability of an odor to spread throughout a large volume of air and persist at perceptible levels.

Odor Intensity

Intensity Relationships. The human nose is the ultimate standard against which the intensity of an odor must be evaluated. The response of the human nose to odors is bounded at the lower end of the concentration scale by a threshold value and at the upper end by an objectionability concentration. The threshold concentration can be defined in terms of a detection threshold concentration, at which the odorant concentration just gives an intensity of zero or as a recognition threshold concentration, the concentration at which odor quality can be recognized.[3] The detection threshold limit is used most commonly by researchers although it has been argued that the quality recognition sensation is more reproducible than the detection sensation.[4]

Individual response for detection of odors varies widely; as a result, it is customary to use a panel to determine odor threshold concentration and to report threshold values as the "effective dosage" at which 50 percent of the panelists perceive the odor. Reported threshold concentrations for the same odorant vary widely, not only because of individual response variability, but also because of lack of standardization of techniques for managing of samples and presenting them to observers, and lack of standardization in developing and reporting of threshold odor concentrations and in describing odors precisely as to their physical and chemical nature.

The intensity of an odorant has been observed to vary exponentially with its concentration, as described by the Weber-Fechner Psychochemical Law.[5] The Weber expression is:

$$I = k \ln C \qquad \text{(Equation 1)}$$

Where: I = intensity of odor sensation
k = constant
C = odorant concentration

Several odorants are known to follow this law over very wide ranges. The range of intensity from 0 to 5 covers eight log cycles for ethyl mercaptan, six for butyl thioether, and four for crotonaldehyde.[6]

The intensity characteristics of a mixture of odorants may be independent, counteractive, additive, or synergistic. These interactions can be expressed mathematically for two odorants, A and B, as follows.[7]

Independent: $I_{AB} = k \ln (C_A \text{ or } C_B)$ (Equation 2)

Counteraction: $I_{AB} < k \ln (C_A \text{ or } C_B)$ (Equation 3)

Addition: $I_{AB} = k \ln (C_A + C_B)$ (Equation 4)

Synergism: $I_{AB} > k \ln (C_A + C_B)$ (Equation 5)

Human Olfactory Response. Human odor intensity scales are designed to measure the perceived intensity of some specified characteristic or attribute of a material.[8] The descriptor of the odor may be general (e.g., overall intensity of odor or flavor) or specific (e.g., sweetness of a beverage). This method is not to be used for determining the absolute threshold but may be used with any material or product and for any attribute which can be understood clearly by the subjects. In this type of method trained subjects specifically instructed in the attribute to be evaluated are presented a series of samples. Each sample is rated for intensity with alternative points anchored as follows: none, slight, moderate, large or strong, and extreme.

Olfactory sensitivity is known to be highly variable and is subject to physical as well as psychological influences. Some of the factors which have been reported to influence the olfactory sensitivity are as follows:[9]

(1) Odor sensitivity of the individual observer varies diurnally but maintains a reasonable level of constancy over a group of observers.

(2) The sense of smell is rapidly fatigued, though fatigue for one odor does not necessarily affect the perception of dissimilar odors.

(3) Responses to odors are not totally objective because psychological responses vary in different observers.

(4) The sensitivity of observers varies widely in that some persons are extremely sensitive while others are almost insensitive to odors; sensitivity decreases with age.

The above factors have significant impact on the interpretation of subjective data developed under either in situ or laboratory conditions. The order of presentation of sample is of paramount importance as is the time of exposure of the observer to a sample. Inasmuch as the olfactory sense can become fatigued (or acclimated) within a time period (or adjustment time), exposure for a duration greater than adjustment time can lead to diminution or loss of odor perceptiveness. Because of adjustment time subjective data must be interpreted relative to the exposure context in which it was developed, viz.:

(1) Laboratory exposure: exposure time < adjustment time.
(2) Field exposure: exposure time > adjustment time.
(3) Field exposure: exposure time < adjustment time.

Case (2) occurs when one enters and remains in an odorified atmosphere; Cases (1) and (3) occur only when the subject undergoes a transient exposure to an odorified atmosphere.

Recognition of an odor problem is related functionally to one's perception of the odor. However, under circumstances of extended exposure, such as everyday life in an area with an odorified atmosphere, perception is minimized due to acclimation. It follows that, under field circumstances, odor problems will be perceived by resident populations primarily under circumstances causing an odorified atmosphere to be present on a transient basis.

Odor Quality

The characteristic of odor quality is normally defined in terms of commonly perceived odors or by associating unfamiliar with familiar odors. An observer often does not possess the vocabulary to describe the odors he perceives inasmuch as humans can distinguish between hundreds of thousands of odors. Often, quality of an odor may change with dilution of the odor. In the case of an odorant mixture, a more pervasive odorant in the mixture may alter the odor quality significantly as the less pervasive, more concentrated odorant is diluted.

Several odor quality classifications exist, three of which are presented below:[10]

(1) Henning's odor classification

(a)	Spicy:	conspicuous in cloves, cinnamon, nutmeg, etc.
(b)	Flowery:	conspicuous in heliotrope, jasmine, etc.
(c)	Fruity:	conspicuous in apple, orange oil, vinegar, etc.
(d)	Resinous:	conspicuous in coniferous oils and turpentine.
(e)	Foul:	conspicuous in hydrogen sulfide and products of decay.
(f)	Burnt:	conspicuous in tarry and scorched substances.

(2) Crocker-Henderson classification

(a) Fragrant or sweet
(b) Acid or sour
(c) Burnt or empyreumatic
(d) Caprylic, goaty or oenanthic

(3) Horstman classification of odor descriptors

(a) Flowers
(b) Pulp mill
(c) Smoke, woodsmoke
(d) Burning leaves
(e) Mustiness
(f) Gasoline
(g) Rendering plant
(h) Rubbish burning
(i) Animal odors
(j) Miscellaneous odors

Of the above three classifications, the Horstman system represents the most serious attempt to categorize odor qualities in terms of commonly-understood descriptors.

Odor Acceptability

An odor may be acceptable or unacceptable depending on its intensity and quality. The acceptability of an odor is related to individual perferences which are known to be related to age, sex, vocation and environment. Odor acceptability is of immediate relevance in evaluation of field odor problems in that odors acceptable to some individuals on a permanent basis may not be acceptable to others on a transient basis. Likewise, odorants (such as perfumes) acceptable at one concentration may not be acceptable at another.

Odor Pervasiveness

Odor pervasiveness is the characteristic by which odors persist at detectable concentration levels over wide ranges of concentration. Pervasiveness is often quantitated in terms of odor potential or threshold dilution ratios. The odor unit has been defined to describe the number of dilutions necessary to reduce the odor to the threshold concentration. An odor unit is equal to the volumes of air necessary to dilute the concentration of odorant in one volume of air to the threshold concentration.[11] Pervasiveness is indicated mathematically by the k value in the Weber-Fechner relationship (Equation 1), pervasiveness increasing as the value of k decreases.

DEVELOPMENT OF AGGREGATE ODOR CHARACTERISTIC COEFFICIENTS

At the outset of this study, it was desired to develop a means of estimating for a specific area the odor producing potential resulting from the presence of odor-generating activities. The work was designed so that the information obtained in pursuing this aim would:

(1) Represent the aggregate effects of a specific source, including the quality, intensity, acceptability, and pervasiveness of odors attributable to the source.

(2) Include a measure of the production activity causing the odorant emission.

(3) Locate specifically a cross-sectional representation of potential sources of odorant emissions, in terms of state, city, and street address.

(4) Provide a preliminary estimate of the odor producing potential in a given area as a summation of the subproducts of the aggregate odor characteristic coefficients and an activity measure for the representation of odorant emitting production activities in the area.

The utility of an estimate of the odor producing potential in each such area in the United States would be to aid in selecting cities for the purpose of conducting technical field investigations and public opinion surveys and to provide a parameter which could be related, on a neighborhood scale, to the actual levels of odor pollution observed during technical and public opinion surveys.

Difficulty was encountered, however, in attempting to include odor-generating activities of natural or unexpected origin, e.g., the decomposition of sea life or a neighbor burning trash. The principal problem was in locating a sufficient number of these sources within budgetary constraints. Therefore, attention was directed principally at the most easily found sources — industrial odorant sources.

Thus, the procedures used in developing a means of estimating the odor producing potential of industrial odorant sources were as follows:

(1) A set of aggregate odor characteristic coefficients was developed by first identifying major sources of odor emissions and the physico-chemical nature of the emissions from these sources, by classifying the sources by SIC code, and then by subjectively assigning a quartile ranking to the sources based on the characteristics of the odorants emitted. This work was done by Engineering-Science, Inc. It is described in the following pages of this chapter.

(2) An indirect measure of production activity (number of employees) was selected by Copley International Corporation, which could be tied readily to a specific potential emitter (an industrial plant) by SIC code using information available for purchase from Dun & Bradstreet, Inc.

(3) Computer tabulation techniques were then used by CIC to develop estimates of the odor producing potential of groupings of industrial plants throughout the United States. Additional details of the procedures used and assumptions made in selecting the activity measure and developing these estimates are included in Chapter III.

It is recognized that there are several assumptions inherent specifically in the designation of a quartile ranking for an odor emission and tying that ranking broadly to all sources across the nation falling within an SIC category. The key assumptions are that:

(1) All industries within an SIC classification are potential sources of odorant emissions. (The scope of the study precluded the identification of which industries within an SIC category were not odorant emitters of concern.)

(2) The level of manufacturing process technology and emission control technology varies widely with age of plant, specific mission, corporate policy, etc. (No consideration could be given to this factor for the spectrum of facilities found in an SIC code.)

In addition to the above qualifications, the literature was found to be devoid of information by which to establish a proportionality between:

(1) Technological progress and a generalized statement of how this has attenuated odorant emission.

(2) Units of raw material consumption or production and units of odorant emission.

(3) Units of raw material consumption within an SIC aggregation of industries and any of the activity information provided by Dun & Bradstreet, Inc.

The broad scope of these qualifications was necessary for the development of preliminary estimates of odor producing potential. It is emphasized that the justification for this effort is the utility of these estimates in problem area identification, which is one of the principal objectives of this study.

Identification of Odor Producing Air Pollutants

Major odor producing air pollutants were identified by class of chemical compound, class of combustion process, and category of industrial activity from the basic reference literature.[12] The information is assembled in Appendix A in the following format:

(1) Table A-I: Major Odor Producing Air Pollutants, Olfactory Thresholds and Related Data. Pollutants are identified by class of chemical compound.

(2) Table A-II: Odorous Emissions From Combustion. Pollutants are identified by class of combustion process.

(3) Table A-III: Odorous Emissions From Industrial Operations. Pollutants are identified by industrial category and process within category.

Industrial Odor Rankings

As an initial step in developing a means of estimating the odor producing potential of industrial odorant sources, a tentative set of industrial odor rankings was devised based on the assumption that those industries emitting the strongest odorants are the most likely to cause odor problems. These tentative odor rankings were developed as follows:

(1) Those industries which were known to be potential sources of odor emission were identified, along with the major odorants associated with each.

(2) The odorants were assigned a ranking of from one to four on the basis of odor strength, as measured by concentrations required to produce threshold perception (using data summarized in Appendix A).

(3) The industries were assigned a quartile ranking based on the rankings assigned to the industries' characteristic odorants.

The industrial odor rankings developed in this manner were then reviewed subjectively to evaluate the correspondence of these rankings to the odor problem levels of the industries involved as reported qualitatively in the literature. As a result of the subjective review, a set of aggregate odor characteristic coefficients was established.

Development of Tentative Rankings Based on Odorant Strength. The standard methods for the measurement of odorant strength are based on differing levels of human response. The threshold, or perception, concept expresses odorant strength in terms of the minimum concentration required for perception. Other methods of odorant measurement are based on the concentration required for some higher level of response to the odorant involved (beyond mere perception) as expressed in terms of the perception concentration (C_t) multiplied by the intensity factor (F) raised to the appropriate power as reported in Table I.[13]

Two levels of response were used as the basis for odorant strength rankings. One set of rankings was developed on the basis of concentrations required for threshold perception, and another set was based on concentrations required to produce the most intense effect defined in the literature, usually stated as "very strong." These concentrations were obtained using the expressions shown in Table I and a compilation of odorant constants C_t and F obtained from the literature.

In both cases the odorants were arranged in order of decreasing concentration required to produce a given level of response. This list was divided into four roughly equal groups, and the odorants in the first group were assigned a rank of 1, those in the second group a rank of 2, and so on.

In general, the two sets of odorant rankings thus obtained were similar. The set based on threshold response was used in developing the tentative industrial odor ranking because it was based on more complete data (some F values were not available for the intense effect rankings), and because they tended to agree more closely with a consensus of opinion on odorant effects found primarily in the literature. These rankings are presented in Table II.

Table I

LEVELS OF RESPONSE TO ODORANTS

Level of Response	Concentration
Perception	C_t
Faint (weak, readily perceptible)	$C_t F$
Easily noticeable (moderate	$C_t F^2$
Strong (forcible)	$C_t F^3$
Very strong (intense effect)	$C_t F^4$

Source: Elmer Kaiser, "Odor and Its Measurement," Air Pollution, Vol. I., ed. Arthur C. Stern (New York: Academic Press, 1962).

Table II

ODORANT RANKINGS

Odorant	Ranking
Sulfur Dioxide	2
Hydrogen Sulfide	4
Sulfides	2
Mercaptans	4
Ammonia	1
Amines	4
Selenium Compounds	4
Hydrocarbons	1
Alcohols	1
Phenol	2
Esters	2
Ethers	1
Aldehydes	3
Ketones	2
Carboxylic Acids	3
Hydrochloric Acid	1
Unsaturated Alcohols, Ethers, Ketones, Acids	3
Iron Oxides	1
Halogens	1

Source: Engineering-Science, Inc.

Odor Characteristic Coefficients

The principal odorant characteristics of different industries are compiled in Appendix A. This list was used to obtain rankings for each industry by using a number which equalled the sum of the rankings shown in Table II for each odorant listed for a particular industry. The values obtained were then ranked on a one to four scale.

The industrial odor rankings obtained in this manner were subsequently reviewed in the light of the problem levels of the industries involved, as reported qualitatively in the literature. In general, the odor rankings were supported by the literature in that those industries most often reported as causing odor problems in the literature tended to have highest rankings, however, some rankings were modified.

The industrial odor rankings developed on the basis of characteristic odorant strength are presented in Table III ("Calculated Rank" column), together with the odor characteristic coefficients established on the basis of the subjective review described above ("Odor Characteristic Coefficients" column). The coefficients were recommended for use in conjunction with a measure of production activity in estimating the odor producing potential of groupings of industrial plants.

It is emphasized that the odor characteristic coefficients do not reflect directly the influence of the numerous variables related to human odor perception, as discussed in the first section of this chapter. In particular, no account is taken of the effects of human response to a continuous odor (olfactory fatigue), the combined effects of different odorants, e.g., masking phenomena, and the importance of odor variations relative to average odor intensities. However, in view of the constraints of data availability noted earlier, it is believed that the set of aggregate odor characteristic coefficients presented here represents a reasonable empirical response to the industrial odor ranking requirement.

Table III

INDUSTRIAL ODOR RANKINGS

Type of Industry	SIC Code	Calculated Rank	Odor Characteristic Coefficient
Incinerators	4952	4	2
Open Burning	4953	4	4
Pulp and Paper	2611	4	4
	2621	4	4
	2631	4	4
Cement Production	3241	1	1
Glass and Ceramics	3211	1	1
	3229	1	1
Asphalt and Bituminous	2951	1	3
Iron and Steel Production	3312	4	2
Iron and Steel Foundries	3321	3	2
	3322	3	2
	3323	3	2
Copper Smelting and Refining	3331	3	3
Lead Sintering	3332	3	3
Titanium	3339	1	1
	3341	1	1
Zinc	3333	1	1
	3341	1	1
Aluminum	3334	1	1
	3341	1	1
Non-Ferrous Foundries	3361	3	3
	3362	3	3
	3369	3	3

Table III (Cont'd)

Type of Industry	SIC Code	Calculated Rank	Odor Characteristic Coefficient
Industrial Inorganic Chemicals	2819	2	2
Alkalis	2812	1	1
Fertilizers	2871	2	3
Petroleum Refineries	2911	3	2
Organic Chemicals	2815	4	3
	2818	4	3
	2821	4	3
	2822	4	3
	2823	4	2
	2824	4	2
	2833	4	3
	2841	4	2
	2842	4	3
	2844	4	3
	2851	4	4
	2861	4	4
Animal Production	4731	2	4
Meat Packing	2011	4	4
	2015	4	4
Fish Processing	2031	4	4
	2036	4	4
Fruit and Vegetable Processing	2033	4	2
Coffee Roasting	2072	-	3
	2095	-	3
Breweries	2082	-	2
	2085	-	2

Source: Engineering-Science, Inc.

Notes

1. Norman A. Huey, et al., "Objective Odor Pollution Control Investigations," Journal of the Air Pollution Control Association, X, No. 6 (December, 1960), pp. 441-446.

2. Amos Turk and Stanley Mehlman, "Correlations Between Instrumental and Sensory Characterization of Atmospheric Odors," Correlation of Subjective-Objective Methods in the Study of Odors and Taste, Special Technical Publication No. 440 (American Society for Testing and Materials, 1968), p. 27.

3. Ralph J. Sullivan, Air Pollution Aspects of Odors (Bethesda, Maryland: Litton Systems, Inc., 1969), draft copy, pp. 6-8.

4. G. Leonardos, D. Kendall and N. Bernard, "Odor Threshold Determinations of 53 Odorant Chemicals," Journal of the Air Pollution Control Association, XIX, No. 2 (February, 1969), p. 91.

5. Sullivan, op. cit., draft copy, p. 5.

6. J. F. Byrd and A. H. Phelps, Jr., "Odor and Its Measurement," Air Pollution, Vol. II, ed. A. C. Stern (2nd ed.; New York: Academic Press, 1968), pp. 305-327.

7. Sullivan, op. cit., draft copy, p. 6.

8. Manual on Sensory Testing Methods, Special Technical Publication No. 434 (American Society for Testing and Materials, 1968), p. 33.

9. S. W. Horstman, R. F. Wromble and A. N. Heller, "Identification of Community Odor Problems by Use of an Observer Corps," Journal of the Air Pollution Control Association, XV, No. 6 (June, 1965), p. 261.

10. Ibid., and Sullivan, op. cit., draft copy, p. 10.

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11. Sullivan, op. cit., draft copy, p. 12.

12. W. Summer, Methods of Air Deodorization (Amsterdam: Elsevier, 1963), and Arthur C. Stern (ed.), Air Pollution, Vol. III (2nd ed.; New York: Academic Press, 1968).

13. J. F. Byrd and A. H. Phelps, Jr., "Odor and Its Measurement," Air Pollution, Vol. I, ed. Arthur C. Stern (New York: Academic Press, 1962).

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CHAPTER III

ODOR PRODUCING POTENTIAL OF INDUSTRIAL ODORANT SOURCES

This chapter describes the process of relating the quartile ranking of odors, developed by Engineering-Science, Inc., to nationwide groupings of industrial plants known to be potential sources of odorant emissions. Working on the assumption that odorant emission varies directly with plant output, Copley International Corporation developed a ranking system for a measure of plant output to be applied as an additional weighting factor in establishing this relationship.

The chapter is divided into two sections: The first describes the selection of number of employees as a measure of plant output; the second indicates the method of weighting nationwide groupings of industrial plants by a set of odor characteristic coefficients and a measure of relative output.

SELECTION OF NUMBER OF EMPLOYEES AS A MEASURE OF PLANT OUTPUT

Plant output may be basically defined as the quantity of something produced from scarce resources for consumption or further production. In order to measure the output of a plant within a single product industry, it is only necessary to establish a standard of quantity and a standard of time as a frame of reference. Once a frame of reference is established, it is a simple matter to compare the outputs of two or more plants in absolute or relative terms. For example, one crude oil plant may produce 100 barrels of oil per day, while a second crude oil plant produces 200 barrels of oil per day or twice as much as the first plant.

Within a multi-product industry, however, the measurement of plant output becomes more complex when different standards of quantity are established for each product. Thus, the crude oil plant may produce 100 barrels of oil per day and 100 tons of coke per day.

This problem is discussed by Caleb A. Smith in his "Survey of the Empirical Evidence on Economics of Scale." He states that:

> "....The measurement of output is unequivocal only if the output is homogeneous. In practice we do not find either plants or firms which, during a period of growth from small-scale to large-scale, produced one homogeneous product, nor do we find a group of plants or firms of widely different size which produce a single homogeneous product.

> Output of plants and firms is in fact heterogeneous to a very substantial extent.
>
> "....When we talk about the size of a plant or firm we ordinarily mean its capacity to turn out its entire product mix, not its capacity to turn out one specific product."[1]

To simplify the comparison of the outputs in multi-product industries, it is often convenient to establish a standard of quantity that relates to some single attribute common to the production of each output. Indeed, when comparing the output of plants included in an aggregation such as the Standard Industrial Classification (SIC) system, it is necessary to establish such a surrogate standard.

The most meaningful surrogate standard of quantity would be the average cost per unit of output. But, unfortunately, this type of cost information is not readily available. Competitive and other pressures generally restrain plant managers from publishing such information. While average cost per unit estimates are available for a few types of production — principally for the production of basic raw materials — there are none available for the SIC aggregations used in this study.

Some information that is published by firms, especially publicly held corporations, could possibly be used as surrogate standards of quantity. This information includes such statistics as sales volume, income generated or value added, the value of assets and the number of employees. It is usually published annually, and frequently, for each quarter year.

These statistics have been used by economists to represent plant size as a measure of industrial concentration in any given market — see, for example, "Measurement of Industrial Concentration," by Morris A. Adelman[2] and "Measurement of Concentration," by Gideon Rosenbluth.[3] Such statistics could also be used to represent a measure of relative output of plants within the same industry. In either usage, however, they are subject to the following criticisms.

Sales Volume

If the mix of products sold varies from plant to plant, sales volume may not be representative of differences in the levels of output. This would be especially true if there is a substantial difference in the market price for each of the products produced.

Income Generated Or, Similarly, Value Added

It is generally agreed that the best single measure of industrial concentration is income generated within the plant. This measurement is quite similar to the value added by manufacture measurement used by the Bureau of the Census in the 1947 Census of Manufactures.[4] Unfortunately, this statistic is not published by many firms. It could be closely estimated by (1) subtracting total purchases from other firms from total revenue, or (2) summing total wages, transfer payments for inputs provided by other company-owned operations, and profit. But, such things as total purchases from other firms and transfer payments to other company-owned operations are rarely reported separately in firms' income statements.

Value of Assets

As Adelman states:

> "Assets are the result of accumulation over time. If prices have changed to an appreciable degree, comparisons among firms (or among plants) or groups of firms (or groups of plants) are impaired by variations in the time pattern of accumulation....The longer the time period over which the assets have been accumulated, the greater the uncertainty about their valuation on a common basis."[5]

Number of Employees

One problem with using number of employees to represent a measure of output of plants within the same industry is again related to product mix. Even if the same products are produced at all plants in an industry, these products may be produced in different relative proportions at each plant. The problem with using number of employees manifests itself when the quantity of labor required to manufacture a unit of one product is more or less than that required to manufacture a unit of each of the other products at a given plant. (A similar criticism may be developed against using the value of assets, since a unit of one product may require more or less asset intensity as well as more or less labor intensity.)

One final obstacle was encountered in the search for a measure of plant output. While sales volume, value of assets, and number of employees are published at least annually by publicly held corporations, these statistics are typically an aggregate for all plants owned by each corporation. Statistics for the individual plants are not published.

One statistic — number of employees — is collected annually for individual plants in the United States by Dun & Bradstreet, Inc. It is available to clients along with other aggregate firm data through Dun's Market Identifiers service. Therefore, in spite of the criticisms identified above, for the purpose of this study number of employees was chosen as the measure of plant output.

METHOD OF WEIGHTING NATIONWIDE GROUPINGS OF INDUSTRIAL PLANTS

Copley International Corporation obtained a magnetic computer tape from Dun's Market Identifiers service that contains the names, addresses, five-digit postal zip codes, and numbers of employees of approximately thirty thousand industrial plants located throughout the United States. Each of these plants is included in at least one of forty-eight SIC classifications of industries known to be potential sources of odorant emission. Table I lists the number of these plants with a primary line of business in the corresponding SIC classification.[6]

Table I

NUMBER OF PLANTS WITH A PRIMARY LINE OF BUSINESS IN A CORRESPONDING SIC CLASSIFICATION

SIC*	Description	No. of Plants
2011	Meat packing plants	2,434
2015	Poultry and small game dressing and packing, wholesale	518
2031	Canned and cured fish and sea foods	355
2033	Canned fruits, vegetables, preserves, jams and jellies	1,321
2036	Fresh or frozen packaged fish and sea foods	340
2072	Chocolate and cocoa products	70
2082	Malt liquors	168
2085	Distilled, rectified, and blended liquors	151
2095	Roasted coffee	161
2611	Pulp mills	108
2621	Paper mills, except building paper mills	481
2631	Paperboard mills	279
2812	Alkalies and chlorine	114
2815	Cyclic intermediates, dyes, organic pigments (lakes and toners), and cyclic (coal tar) crudes	233
2818	Industrial organic chemicals, not elsewhere classified	747
2819	Industrial inorganic chemicals, not elsewhere classified	991
2821	Plastics materials, synthetic resins and nonvulcanizable elastomers	1,353
2822	Synthetic rubber (vulcanizable elastomers)	111
2823	Cellulosic man-made fibers	52
2824	Synthetic organic fibers, except cellulosic	79
2833	Medicinal chemicals and botanical products	311
2841	Soap and other detergents, except specialty cleaners	787
2842	Specialty cleaning, polishing, and sanitation preparations, except soap and detergents	1,822
2844	Perfumes, cosmetics and other toilet preparations	1,078
2851	Paints, varnishes, lacquers, enamels and allied products	2,029
2861	Gum and wood chemicals	216
2871	Fertilizers	719

* The forty-eight SIC classifications included in this table do not represent an exhaustive list of odorant emitting industries, but rather a cross-section of potential sources.

Table I (Cont'd)

SIC*	Description	No. of Plants
2911	Petroleum refining	593
2951	Paving mixtures and blocks	926
3211	Flat glass	87
3229	Pressed and blown and glassware, not elsewhere classified	424
3241	Cement, hydraulic	270
3312	Blast furnaces (including coke ovens), steel works, and rolling mills	586
3321	Gray iron foundries	972
3322	Malleable iron foundries	127
3323	Steel foundries	312
3331	Primary smelting and refining of copper	36
3332	Primary smelting and refining of lead	28
3333	Primary smelting and refining of zinc	39
3334	Primary production of aluminum	74
3339	Primary smelting and refining of non-ferrous metals, not elsewhere classified	113
3341	Secondary smelting and refining of non-ferrous metals	325
3361	Aluminum castings	1,079
3362	Brass, bronze, copper, copper base alloy castings	687
3369	Nonferrous castings, not elsewhere classified	512
4731	Stockyards	117
4952	Sewerage systems	79
4953	Refuse systems	1,442
	Total	25,856

* The forty-eight SIC classifications included in this table do not represent an exhaustive list of odorant emitting industries, but rather a cross-section of potential sources.

Source: Dun's Market Identifiers service.

Groupings of Plants in Postal Zip Code Areas

As a convenient means of locating nationwide groupings of a cross-section of industrial odorant sources, the 25,856 industrial plants included in Table I were sorted by five-digit postal zip code. It was planned to weight the number of plants in each of these groupings by a set of odor characteristic coefficients and a measure of relative output, and then to plot the weighted values on a five-digit zip code area map of the United States. This was to provide a graphical representation of the odor producing potential of industrial odorant sources in each five-digit area. However, this plan was necessarily modified.

In response to an inquiry, the Post Office Department stated that a five-digit area map of the United States is not available. A map of unwieldly proportions would be required to delineate all of the approximately 38,000 five-digit zip code areas in the United States. As an alternative, they recommended use of their three-digit area map, which outlines the 837 three-digit zip code areas established across the nation. (A three-digit zip code area includes all five-digit zip code areas having the same first three digits; thus, area 921 would include areas 92101, 92102, 92103, etc.) Following this recommendation, the five-digit groupings of industrial odorant sources were summarized into appropriate three-digit groupings.

A ranking of the number of industrial plants in each three-digit zip code area indicated that industrial odorant sources are centered principally in the metropolitan areas of the United States.[7] Table II presents a ranking of the fifty metropolitan areas having the largest number of the 25,856 industrial plants included in Table I. Note that fifty-eight percent of the plants included in Table I are located in these fifty metropolitan areas.

Certain three-digit zip codes were combined to determine the total number of industrial plants located in each metropolitan area in the nation. The three-digit zip codes included in each of the metropolitan areas of Table II are listed in Appendix B.

Table II

FIFTY METROPOLITAN AREAS IN THE UNITES STATES HAVING THE LARGEST NUMBER OF INDUSTRIAL PLANTS INCLUDED IN TABLE I

Rank	Metropolitan Area	No. of Industrial Plants	Rank	Metropolitan Area	No. of Industrial Plants
1	Los Angeles, CA	1,373	26	Dayton, OH	176
2	New York, NY	1,291	27	Kalamazoo, MI	159
3	Chicago, IL	1,252	28	Indianapolis, IN	155
4	Newark, NJ	1,081	29	Tampa, FL	152
5	Philadelphia, PA-Camden, NJ	819	30	Louisville, KY	151
6	Detroit, MI	556	31	Columbus, OH	146
7	San Francisco-Oakland, CA	543	32	New Haven, CT	145
8	Boston, MA	478	33	New Brunswick, NJ	138
9	Cleveland, OH	475	34	Rochester, NY	136
10	St. Louis, MO-East St. Louis, IL	373	35	Toledo, OH	136
11	Houston, TX	359	36	Santa Ana, CA	131
12	Milwaukee, WI	314	37	White Plains, NY	131
13	Pittsburgh, PA	301	38	Denver, CO	129
14	Providence, RI	264	39	New Orleans, LA	119
15	Minneapolis-St. Paul, MN	257	40	Birmingham, AL	117
16	Portland, OR	243	41	Charlotte, NC	111
17	Cincinnati, OH	233	42	San Jose, CA	111
18	Dallas, TX	230	43	Canton, OH	109
19	Baltimore, MD	227	44	Syracuse, NY	108
20	Atlanta, GA	223	45	Fort Worth, TX	106
21	Buffalo, NY	218	46	Hicksville, NY	104
22	Miami, FL	210	47	Greensboro, NC	101
23	Seattle, WA	205	48	Albany, NY	100
24	Grand Rapids, MI	186	49	Memphis, TN	98
25	Kansas City, KS-Kansas City, MO	184	50	Chattanooga, TN	93

Source: Copley International Corporation

The final step in establishing the odor producing potential of industrial odorant sources was to weight the numbers of industrial plants in each three-digit zip code area by a set of odor characteristic coefficients and a measure of relative output.

Weighting by Odor Characteristic Coefficients

A set of aggregate odor characteristic coefficients was developed by Engineering-Science, Inc., on the assumption that those industries emitting the strongest odorants are most likely to cause odor problems. This effort is described in Chapter II.

Weighting by Relative Output

Rather than to assume a single relationship between the levels of odorant emission and plant output as represented by numbers of employees, two different weighting functions were developed, which were called "linear" and "linear-modified."

The linear weighting function is based on the assumption that odorant emission varies in direct proportion to plant output. It may be algebraically stated as follows.

$$\text{(linear)} \quad w_{i_j} = 10 \times \frac{E_{i_j}}{E_{1_j}}$$

where: w_{i_j} = the relative output weight applied to plant i of SIC classification j.

E_{i_j} = the number of employees (representing the output) of plant i of SIC classification j.

E_{1_j} = the number of employees (representing the output) of the largest plant of SIC classification j.

For each SIC classification, a minimum weight less than one was given to the plant with the fewest employees and a maximum weight of ten was given to the plant with the most employees.

The linear-modified weighting function is based on the assumption that odorant emission varies in direct proportion to plant output for smaller and medium-sized plants, but that odorant emission becomes constant for larger plants. This reflects the possibility that managers of larger plants are more concerned about maintaining good relations with nearby residents and businesses; thus, they attempt to control odorant emission beyond some acceptable level.[8] The function may be algebraically stated as follows:

(linear-modified) $w_{i_j} = 8$, for all plants included in the 20 percent having the largest number of employees, and

(linear-modified) $w_{i_j} = 8 \times \frac{E_{i_j}}{E_{1_j}}$, for all plants not included in the 20 percent having the largest number of employees.

Thus, for each SIC classification, plants were divided into two groups. The first group consisted of all plants included in the twenty percent having the largest number of employees. These plants were given a weight of eight. The second group consists of the remaining plants, with each given a weight ranging linearly from less than one for the smallest plant to eight for the largest plant in the group.

Table III indicates the distribution of plants within twelve ranges of number of employees for each SIC classification listed in Table I. The typical distribution shows a positive skewness, with a majority of plants having less than 300 employees. Figure 1 indicates the weights that would be given to a cumulative percentage of a typically skewed distribution of plants. Note that the linear weighting function emphasizes a small percentage of plants having large numbers of employees, while the linear-modified function gives relatively more emphasis to smaller and medium-sized plants.

Table III

DISTRIBUTION OF PLANTS INTO TWELVE RANGES OF NUMBER OF EMPLOYEES - BY SIC CLASSIFICATION

SIC \ Range of Employees	0-9	10-19	20-39	40-99	100-299	300-599	600-999	1000-2999	3000-5999	6000-9999	10,000-29,999	30,000 or more
SIC 2011	1048	296	262	267	191	51	22	20	5	0	0	0
SIC 2015	77	35	52	66	136	35	5	3	1	0	0	0
SIC 2031	74	28	33	39	34	7	3	1	0	0	0	0
SIC 2033	236	114	105	131	121	38	11	8	1	0	0	0
SIC 2036	74	43	42	40	26	5	1	0	0	0	0	0
SIC 2072	23	5	3	12	11	0	1	0	1	0	0	0
SIC 2082	5	1	14	20	45	31	11	11	2	0	0	0
SIC 2085	19	19	9	36	20	12	7	2	1	0	0	0
SIC 2095	40	22	19	21	18	8	1	1	0	0	0	0
SIC 2611	30	7	5	3	14	11	11	9	1	0	0	0
SIC 2621	37	21	25	65	113	58	34	39	6	0	0	0
SIC 2631	23	7	18	41	88	31	12	5	1	0	0	0
SIC 2812	23	13	12	7	12	3	7	6	0	0	0	0
SIC 2815	78	35	27	26	18	7	7	1	0	0	0	0
SIC 2818	233	101	86	64	60	32	11	12	2	0	2	0
SIC 2819	337	108	115	122	87	35	17	9	1	0	0	0
SIC 2821	383	196	171	163	148	33	16	15	3	0	0	0
SIC 2822	35	12	11	8	12	4	10	2	0	1	0	0
SIC 2823	3	4	10	4	6	2	2	8	4	0	0	0
SIC 2824	12	3	10	9	12	8	3	6	4	2	0	0
SIC 2833	119	28	20	28	28	7	4	4	1	0	0	0
SIC 2841	430	89	66	44	23	11	5	4	0	0	0	0
SIC 2842	1061	230	140	101	36	14	1	2	0	0	0	0
SIC 2844	567	116	74	52	51	19	8	11	0	0	0	0
SIC 2851	755	312	299	215	108	27	4	4	0	1	1	0

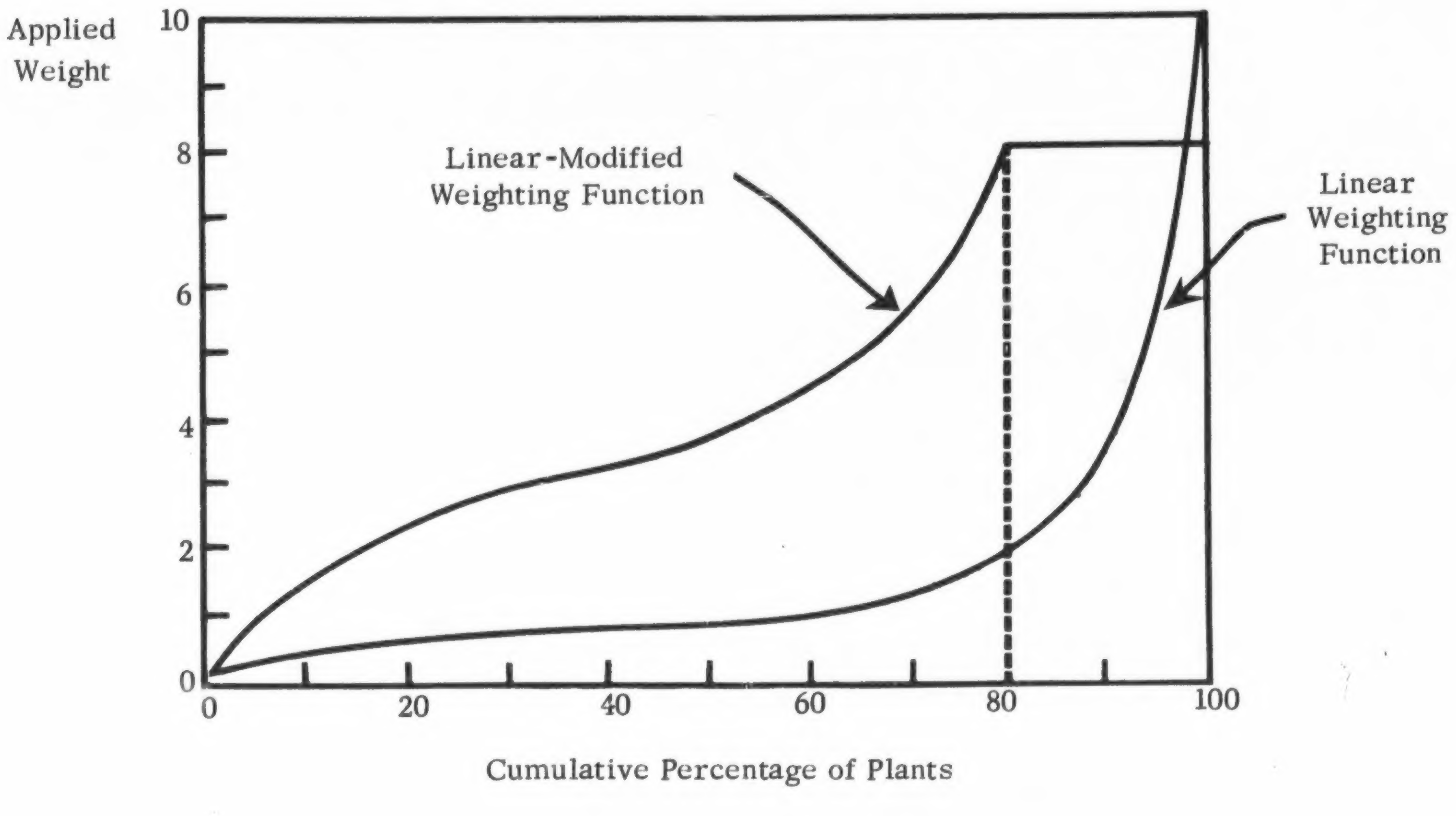
Table III (Cont'd)

SIC \ Range of Employees	0-9	10-19	20-39	40-99	100-299	300-599	600-999	1000-2999	3000-5999	6000-9999	10,000-29,999	30,000 or more
SIC 2861	70	32	22	12	14	5	1	1	0	0	0	0
SIC 2871	215	94	74	89	37	14	2	1	0	0	0	0
SIC 2911	116	53	81	61	73	47	15	16	5	1	1	0
SIC 2951	412	163	89	48	7	3	0	1	0	0	0	0
SIC 3211	19	8	9	5	6	7	6	8	0	0	0	0
SIC 3229	190	34	32	31	37	26	6	11	1	1	0	0
SIC 3241	29	17	15	32	107	12	1	2	0	0	0	0
SIC 3312	87	29	38	44	77	46	30	42	25	10	12	0
SIC 3321	140	88	139	242	180	38	16	9	5	0	0	0
SIC 3322	18	13	15	13	29	16	6	6	0	0	0	0
SIC 3323	37	27	34	53	66	32	10	7	0	0	0	0
SIC 3331	4	4	0	4	2	1	6	8	0	0	0	0
SIC 3332	5	0	4	7	5	3	0	0	0	0	0	0
SIC 3333	4	5	4	4	6	5	2	2	0	0	0	0
SIC 3334	13	3	4	5	4	6	11	12	2	0	0	0
SIC 3339	29	10	13	15	11	6	5	1	0	0	0	0
SIC 3341	94	57	46	39	30	7	3	0	0	0	0	0
SIC 3361	393	177	144	124	100	19	2	7	1	0	0	0
SIC 3362	259	133	102	90	38	3	1	3	0	0	0	0
SIC 3369	150	93	84	55	41	15	3	6	0	0	0	0
SIC 4731	45	19	11	7	2	3	0	0	0	0	0	0
SIC 4952	41	10	2	1	1	0	0	0	0	0	0	0
SIC 4953	791	253	139	47	9	3	0	0	0	0	0	0

Source: Copley International Corporation.

Figure 1

WEIGHTS GIVEN TO A CUMULATIVE PERCENTAGE
OF A TYPICALLY SKEWED DISTRIBUTION OF PLANTS



Source: Copley International Corporation

Application of Weights to Groupings of Industrial Plants

Two weights were computed for each of the 25,856 industrial plants included in the SIC classifications listed in Table I:

$$(\text{linear})\ W_{i_j} = ESI_j \times (\text{linear})\ w_{i_j}, \text{ and}$$

$$(\text{linear-modified})\ W_{i_j} = ESI_j \times (\text{linear-modified})\ w_{i_j}$$

where: W_{i_j} = the weight applied to plant i of SIC classification j.

ESI_j = the odor characteristic coefficient applied to SIC classification j.

w_{i_j} = the relative output weight applied to plant i of SIC classification j.

Following this, two weights were computed for the total number of plants of each SIC classification in a given three-digit zip code area:

$$(\text{linear})\ W_{j_k} = \sum_{i=1}^{m} (\text{linear})\ W_{i_{j_k}}, \text{ and}$$

$$(\text{linear-modified})\ W_{j_k} = \sum_{i=1}^{m} (\text{linear-modified})\ W_{i_{j_k}}$$

where: W_{j_k} = the weight applied to the total number of m plants in SIC classification j, located in three-digit zip code area k.

$W_{i_{j_k}}$ = the relative output weight applied to plant i of SIC classification j, located in three-digit zip code area k.

Finally, two weights were computed for the total number of plants of all SIC classifications in a given three-digit zip code area:

$$(\text{linear})\ W_k = \sum_{j=1}^{n} (\text{linear})\ W_{j_k}, \text{ and}$$

$$(\text{linear-modified})\ W_k = \sum_{j=1}^{n} (\text{linear-modified})\ W_{j_k}$$

where: W_k = the weight applied to the total number of plants of n SIC classifications, located in three-digit zip code area k.

Weighted Value of Groupings of Plants in Metropolitan Areas

After computing the weighted values (linear W_k and linear-modified W_k) for each three-digit zip code area in the United States, certain zip codes were again combined to determine the weighted values of industrial plants located in metropolitan areas.[9] Table IV presents a ranking of the fifty metropolitan areas having the highest linear weighted values. Table V presents a similar ranking of the fifty metropolitan areas having the highest linear-modified weighted values.

A comparison of these tables to each other and to the unweighted rankings in Table II indicates a rather undramatic reordering of the major industrial centers of the United States. Of principal note is the difference in the magnitude of weighted values between Table IV and Table V. This difference should be anticipated, however, because of the typical distribution of plants as indicated in Table III, and because the linear-modified weighting function was developed to emphasize the smaller to medium-sized plants.

Thus, the quartile ranking of odors, coupled with a measure of plant output, was used to identify those geographical areas having a concentration of industrial plants known to be potential sources of odorant emissions. These areas, as might be anticipated, are the major industrial centers of the United States.

Table IV

FIFTY METROPOLITAN AREAS IN THE UNITED STATES HAVING THE HIGHEST LINEAR WEIGHTED VALUES OF INDUSTRIAL PLANTS INCLUDED IN TABLE I

Rank	Metropolitan Area	Weighted Value	Rank	Metropolitan Area	Weighted Value
1	Newark, NJ	873	26	Gary, IN	153
2	Chicago, IL	739	27	Atlanta, GA	150
3	Los Angeles, CA	723	28	Tampa, FL	141
4	New York, NY	673	29	Omaha, NB	141
5	Philadelphia, PA-Camden, NJ	606	30	Green Bay, WI	139
6	St. Louis, MO-East St. Louis, IL	398	31	New Orleans, LA	135
7	San Francisco-Oakland, CA	390	32	New Haven, CT	134
8	Cleveland, OH	331	33	Anchorage, AK	131
9	Detroit, MI	316	34	Indianapolis, IN	128
10	Boston, MA	282	35	Providence, RI	128
11	Milwaukee, WI	275	36	Dayton, OH	118
12	Houston, TX	254	37	Dallas, TX	112
13	Portland, OR	253	38	Harrisburg, PA	105
14	Baltimore, MD	228	39	Norfolk, VA	105
15	Minneapolis-St. Paul, MN	222	40	San Jose, CA	103
16	Buffalo, NY	209	41	Oshkosh, WI	101
17	Pittsburgh, PA	206	42	Jacksonville, FL	100
18	Grand Rapids, MI	198	43	Chattanooga, TN	96
19	Cincinnati, OH	186	44	Richmond, VA	95
20	Kalamazoo, MI	182	45	Seattle, WA	94
21	New Brunswick, NJ	181	46	Birmingham, AL	94
22	Kansas City, KS-Kansas City, MO	162	47	Wilmington, DE	89
23	Louisville, KY	157	48	Miami, FL	87
24	Columbus, OH	156	49	Springfield, MA	84
25	Toledo, OH	153	50	Albany, NY	83

Source: Copley International Corporation

Table V

FIFTY METROPOLITAN AREAS IN THE UNITED STATES HAVING THE HIGHEST LINEAR-MODIFIED WEIGHTED VALUES OF INDUSTRIAL PLANTS INCLUDED IN TABLE I

Rank	Metropolitan Area	Weighted Value	Rank	Metropolitan Area	Weighted Value
1	Newark, NJ	30,521	26	Columbus, OH	3,878
2	Chicago, IL	27,539	27	Toledo, OH	3,840
3	Pittsburgh, PA	24,973	28	Indianapolis, IN	3,732
4	Los Angeles, CA	23,079	29	Gary, IN	3,628
5	New York, NY	21,413	30	Omaha, NB	3,549
6	Cleveland, OH	16,961	31	Dayton, OH	3,260
7	Philadelphia, PA-Camden, NJ	15,697	32	Syracuse, NY	3,026
8	St. Louis, MO-East St. Louis, IL	10,660	33	Madison, WI	2,963
9	San Francisco-Oakland, CA	9,947	34	San Jose, CA	2,740
10	Detroit, MI	9,203	35	Johnson City, TN	2,728
11	Houston, TX	7,287	36	Portland, OR	2,703
12	Baltimore, MD	7,222	37	Providence, RI	2,664
13	Milwaukee, WI	6,872	38	Sioux Falls, SD	2,626
14	Boston, MA	6,814	39	Tampa, FL	2,571
15	Minneapolis-St. Paul, MN	6,741	40	Richmond, VA	2,491
16	Louisville, KY	5,760	41	Kalamazoo, MI	2,450
17	Cincinnati, OH	5,679	42	Chattanooga, TN	2,417
18	Grand Rapids, MI	5,167	43	Albany, NY	2,413
19	Atlanta, GA	5,061	44	Norfolk, VA	2,312
20	Kansas City, KS-Kansas City, MO	4,895	45	Memphis, TN	2,291
21	Buffalo, NY	4,762	46	Miami, FL	2,198
22	New Brunswick, NJ	4,643	47	Seattle, WA	2,181
23	New Haven, CT	4,269	48	New Orleans, LA	2,124
24	Saginaw, MI	4,133	49	Canton, OH	2,123
25	Dallas, TX	4,073	50	Rochester, MN	2,040

Source: Copley International Corporation.

Notes

1. *Business Concentration and Price Policy*, National Bureau of Economic Research (Princeton: Princeton University Press, 1955), pp. 215-6.

2. *Review of Economics and Statistics* (November, 1951).

3. *Business Concentration and Price Policy*, *op. cit*.

4. U.S. Bureau of the Census, *Census of Manufactures*, 1947.

5. Adelman, *Review of Economics and Statistics*, *op. cit*., p. 9.

6. The forty-eight SIC classifications included in this study were taken from the U.S. Bureau of the Budget, *Standard Industrial Classification Manual: 1967*. They do not represent an exhaustive list of odorant emitting industries, but rather a cross-section of potential sources.

7. For purposes of this study, a "metropolitan area" is defined as a city (or contiguous cities) to which the Post Office Department has assigned a unique three-digit zip code number(s) plus the surrounding three-digit zip code area(s).

8. It is acknowledged that constant odorant emission may also result from production factors or established ordinances. In accordance with any of these reasons for constant odorant emission, "larger" plants were arbitrarily defined as those included in the twenty percent having the largest number of employees.

9. Figure 2 of Chapter V illustrates a quartile ranking of the linear-modified weighted values of groupings of industrial plants in each three-digit zip code area in the United States.

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CHAPTER IV

EFFECTS OF THE NATURAL ENVIRONMENT ON ODOR PROBLEMS

The purpose of this chapter is to identify those variables in the natural environment which have a significant bearing on the seriousness of an odor problem in a given area, and to present data relevant to these variables in graphical form for the contiguous United States.

As a preliminary qualification to this chapter, it is noted that summary-type data for the entire United States may have only limited relevance to the severity of an odor problem in any given area because of the extremely localized nature of most odor problems.[1] The presence of an odor problem in a given area is dependent upon the existence of an odorant source (or sources), an odor receptor population, and a transport mechanism to convey the former to the latter. Variables in the natural environment act upon this transport mechanism in two ways which influence the severity of the odor problem, by affecting the amount of dilution which takes place and by affecting the quality characteristics of the odorants emitted.

The odorant properties of substances emitted to the atmosphere may be increased or reduced by means of reactions with other components of the atmosphere such as occurs in photochemical reactions or sorptions onto solid or liquid particulates in the atmosphere. General meteorological data which are collected routinely do not provide a basis for estimating the attenuation of odorant levels. In reference to concentration change, however, general meteorologic data provide a basis for estimating the quantities of dilution air available. Inasmuch as meteorological data generated toward assessing the volume of air mass available for dilution and the exchange rate of the air mass available in that volume provide the only basis for predicting the fate of odorant emissions in an area, the parameters reflecting those phenomena (atmospheric stability and wind character) provide the basis for assessing the effect of meteorology on odorant emissions.

Atmospheric Stability

As shown in Figure 1, the lapse rate is the decrease in temperature with altitude. Normally, lapse rates are positive, i.e., air temperature decreases with altitude, a condition usually associated with "unstable" or vigorously mixed air masses. However, a negative lapse rate may prevail occasionally over a range of altitudes. The mass of air which lies within this range is called an inversion layer and is characterized by a lack of vertical and horizontal mixing.

The elevation of the base of an inversion layer above the ground surface is called the mixing depth and defines the upper limit of the body of air available for the dilu-

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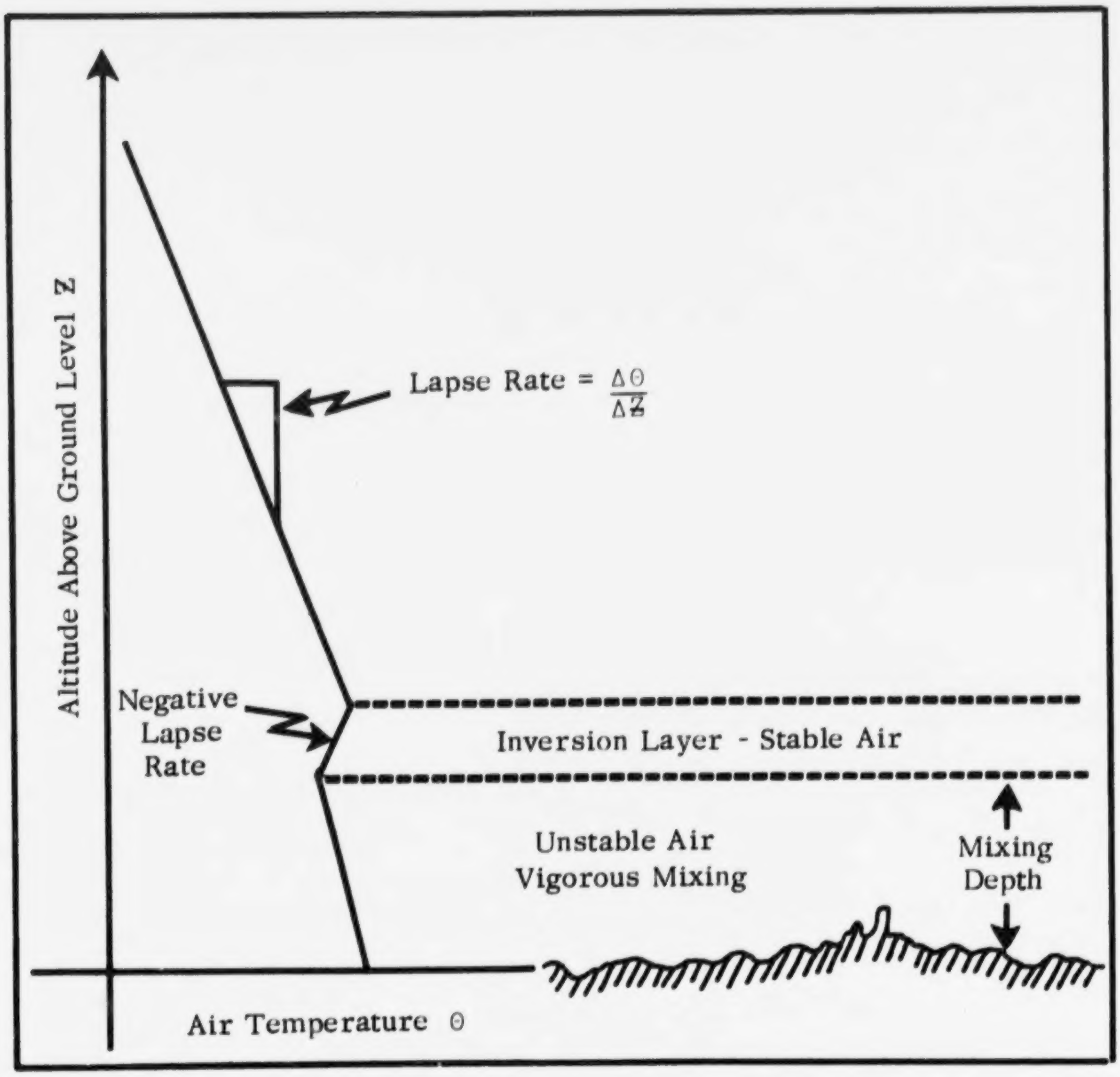
Figure 1

TEMPERATURE GRADIENTS AND ATMOSPHERIC STABILITY


Altitude Above Ground Level Z
Lapse Rate = $\frac{\Delta\Theta}{\Delta Z}$
Negative Lapse Rate
Inversion Layer - Stable Air
Unstable Air Vigorous Mixing
Mixing Depth
Air Temperature Θ

Source: Engineering-Science, Inc.

Low-level stability conditions for the United States have been described by C. R. Hosler[3] in terms of inversion frequency, and by George C. Holzworth[4] in terms of mean maximum mixing depth. Inversion frequency is defined as percent of total hours in which inversions based below 500 feet occur. Maximum mixing depth is defined as the maximum diurnal depth of air column below the inversion layer, as shown in Figure 1. Both approaches are based on vertical temperature gradients, information about which is conventionally established on a diurnal basis by means of radiosonde (balloon-carried transducer) measurements.

Both approaches (inversion frequency and mean maximum mixing depth) share two limitations. The first limitation is based on the fact that most temperature soundings are taken at airports and therefore represent conditions at semi-rural or suburban areas rather than in built-up city areas. The heat radiation and other thermodynamic characteristics of urban areas differ vastly from those of rural areas. As a result, inversions over heavily urbanized areas tend to be based at somewhat higher altitudes than those found above the surrounding countryside.

Another limitation to the utility of inversion frequency and mean maximum mixing depth data is that nothing can be inferred about inversion duration; i.e., the available information is usually not presented in a manner facilitating determination of inversion duration. Obviously, seven days of continuous low-level inversion conditions in a two-week period will have greater impact than inversion conditions which occur on alternate days over the same period.

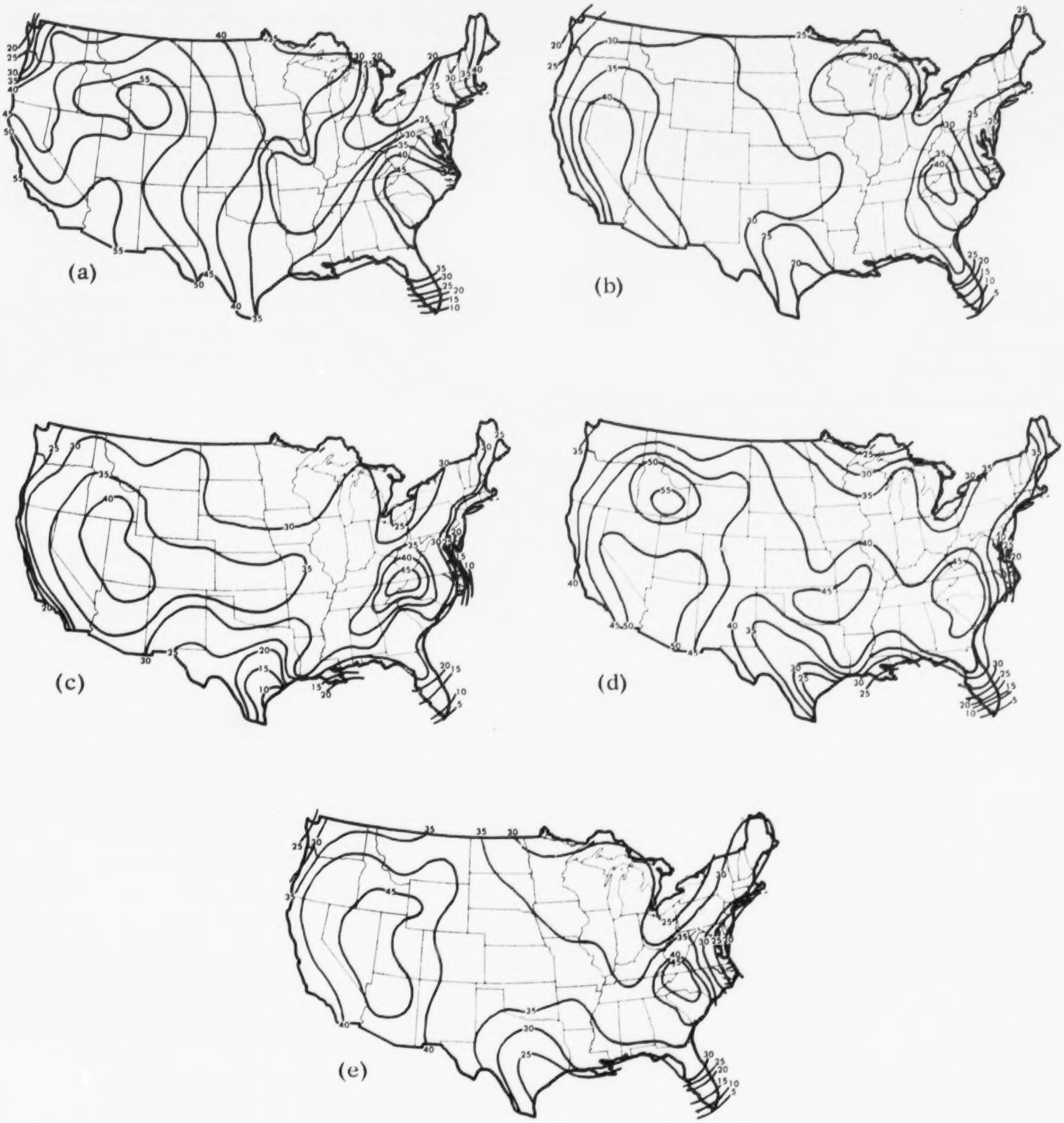
Low-level inversion frequency data for the United States are presented in Figure 2 for each of the four seasons and for the year as a whole. Isopleths are in terms of percent of total hours in which inversions based below 500 feet are present.

The data shown in Figure 2 indicate that highest frequencies of low-level inversions generally occur in mountainous regions. For example, areas having annual frequencies of 45 percent are located in both the Rocky and Appalachian Ranges. The lowest levels of inversion frequency are found along the Mid-Atlantic and Gulf Coasts, and through the Great Lakes.

Estimates of mean monthly values of the maximum mixing depths attained during the diurnal cycle are presented in Figures 3 through 14 for each of the months of the year. All the values shown are for daylight hours because daytime mixing depths are consistently higher than those observed at night.

Figure 2

INVERSION FREQUENCY FOR:
(a) Winter, (b) Spring, (c) Summer, (d) Fall, (e) Annual
(Percent of Total Hours)



Source: C. R. Hosler, "Low-Level Inversion Frequency in the Contiguous United States," Monthly Weather Review, LXXXIX (November, 1961).

A summary of inversion frequency data on an annual nationwide basis is reported in Table I. The range of inversion frequencies is 25-40 percent on an annual basis along the Pacific Coast, 35-45 percent in the Rockies, 30-35 percent in the Midwest, 20-45 percent on the Atlantic States, and 5-25 percent in the Gulf States. (Note that the Atlantic States include Appalachia.) It is apparent that on a year-around basis the Rockies and Atlantic States have the greatest frequencies of inversion.

A summary of monthly mean maximum mixing depth on a nationwide basis is shown in Table II. Maximum values of this parameter are found in summer in all areas of the country, with peak maxima of 3,500 to 4,000 meters occuring in the Rockies.

In order to evaluate the atmospheric dilution capacity in a given area as it relates to atmospheric stability conditions, both mean maximum mixing depth data and inversion frequency data must be taken into account. The inferences which may be drawn from these two sets of data are summarized in Table III. It is seen from Table III that essentially two sets of conditions of mean maximum mixing depth and inversion frequency occur in the United States: low/low, typically occuring in the Pacific States; and high/high, occuring typically in the Appalachians and Rockies.

The Pacific Coast presents an interesting anomaly in that low-level inversion frequencies are among the lowest in the country (see Figure 2) despite the relatively low mean maximum mixing depth values indicated in Figures 3 through 14. This occurs because the criterion used in defining low-level inversion conditions (mixing depth less than 500 feet) causes ocean-induced inversions based above 500 feet to be ignored. These inversions are semi-permanent during spring, summer and fall and are generally based below 2,000 feet.[5]

Table I

SUMMARY OF INVERSION FREQUENCY DATA ON ANNUAL NATIONWIDE BASIS

Season	Range of Inversion Frequencies (Percent)				
	Pacific States	Rockies	Midwest	Atlantic States*	Gulf States
Winter	20-50	> 50	20-40	20-45	5-20
Spring	25-40	35-40	25-30	20-40	5-25
Summer	20-25	35-40	30-35	10-45	5-20
Fall	35-40	45-55	25-45	35-45	5-30
Annual	25-40	35-45	30-35	20-45	5-25

* Atlantic States includes Appalachia.

Source: C. R. Hosler, "Low-Level Inversion Frequency in the Contiguous United States," Monthly Weather Review, LXXXIX (November 1961).

Table II

SUMMARY OF MONTHLY MEAN MAXIMUM MIXING DEPTHS ON NATIONWIDE BASIS

Month	Range of Mean Maximum Mixing Depths (100 meter units)				
	Pacific States	Rockies	Midwest	Atlantic States*	Gulf States
January	4-10	6-10	4	4	6-12
February	6-10	4-12	4	4-6	4-12
March	6-16	14-22	6-10	6-8	6-12
April	6-16	12-26	10-12	4-12	10-14
May	6-16	16-36	10-16	4-14	10-14
June	6-16	18-36	8-18	4-14	12-16
July	4-16	20-40	10-18	4-16	12-20
August	4-16	20-36	10-16	4-12	12-20
September	4-12	12-28	8-12	4-12	12-14
October	4-12	10-18	6-8	4-8	10-12
November	4-8	4-12	2-4	4-8	8-10
December	4-8	4-8	2-4	4-6	6-10

* Atlantic States include Appalachia.

Source: George C. Holzworth, "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XC II (May 1964).

Table III

INTERPRETATION OF ATMOSPHERIC STABILITY DATA WITH RESPECT TO ATMOSPHERIC DILUTION POTENTIAL

Relative Value of Parameter		Area Where Conditions Common	Interpretation
Mean Maximum Mixing Depth	Frequency of Inversion Mixing Depth < 500 Ft.		
Low	Low	Pacific Coast	Continuous low-level inversion based above 500 ft. low dilution capacity.
Low	High	*	Low dilution capacity.
High	High	Appalachians	Frequent low-level inversions at night, with mixing depths usually high during daytime.
		Rockies	Dilution capacity depends on frequency and duration of low daytime mixing depths.
High	Low	*	High dilution capacity.

* These conditions do not commonly occur anywhere in the United States; in most areas normal values are neither exceptionally high nor low.

Source: Engineering-Science, Inc.

Figure 3

MEAN MAXIMUM MIXING DEPTHS ABOVE THE SURFACE DURING JANUARY
(Isopleths Are Labeled in Hundreds of Meters)

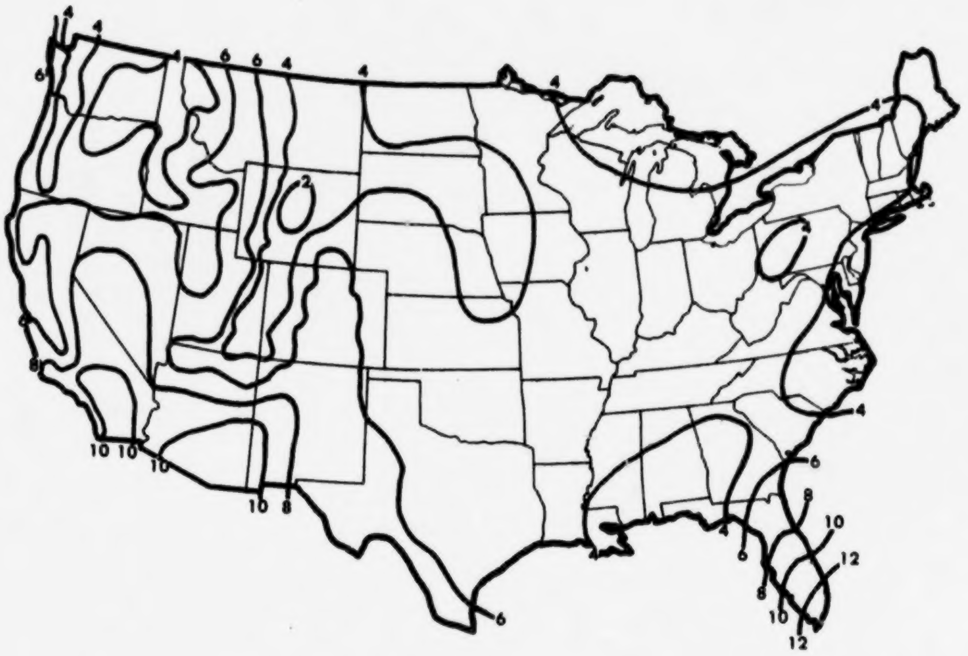

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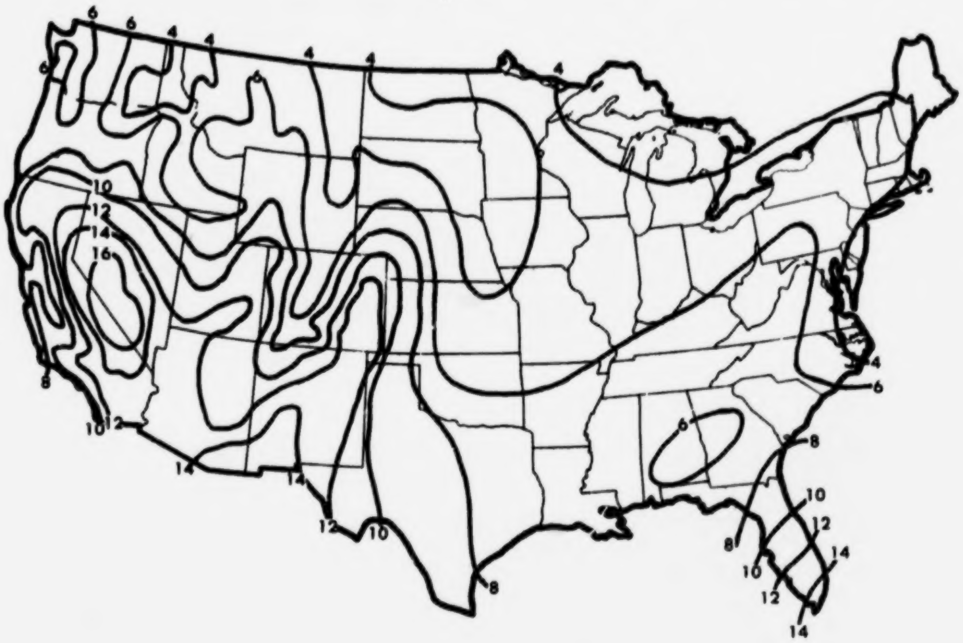
Figure 4

MEAN MAXIMUM MIXING DEPTHS, FEBRUARY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Source: George C. Holzworth, "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XCII (May, 1964).

Figure 5

MEAN MAXIMUM MIXING DEPTHS, MARCH

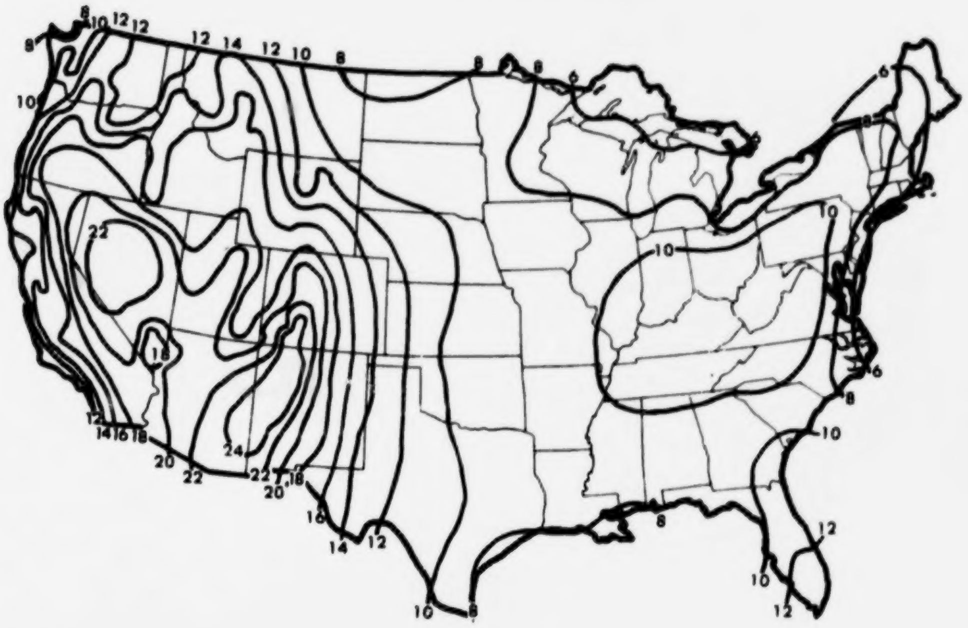
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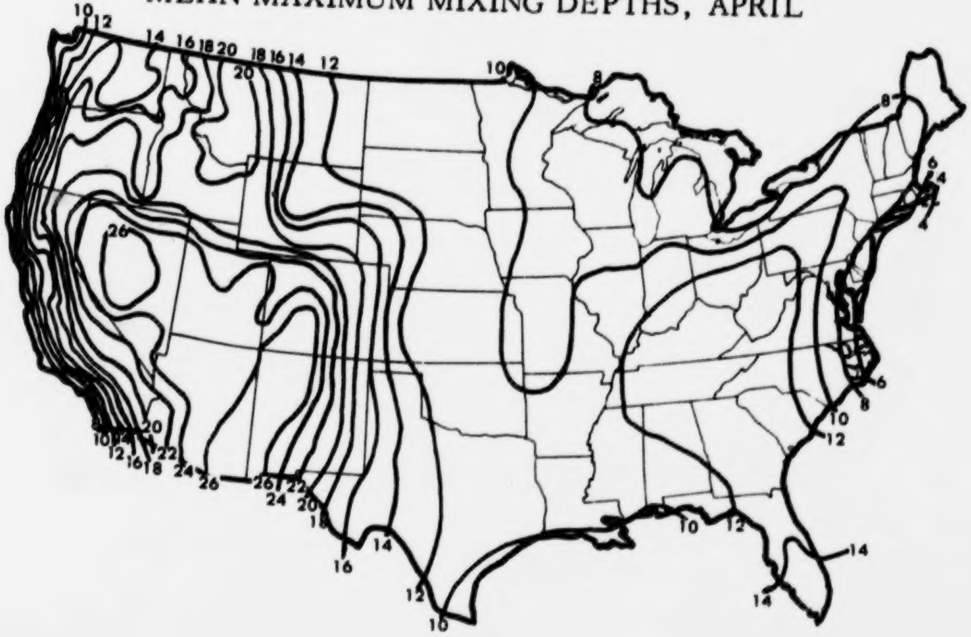
Figure 6

MEAN MAXIMUM MIXING DEPTHS, APRIL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Source: George C. Holzworth, "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XCII (May, 1964).

Figure 7

MEAN MAXIMUM MIXING DEPTHS, MAY

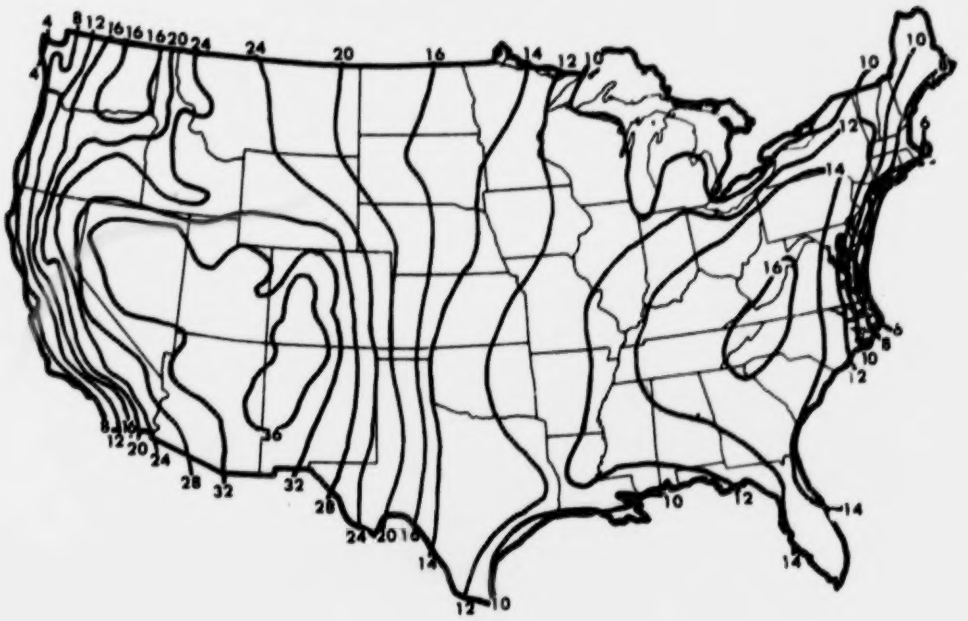
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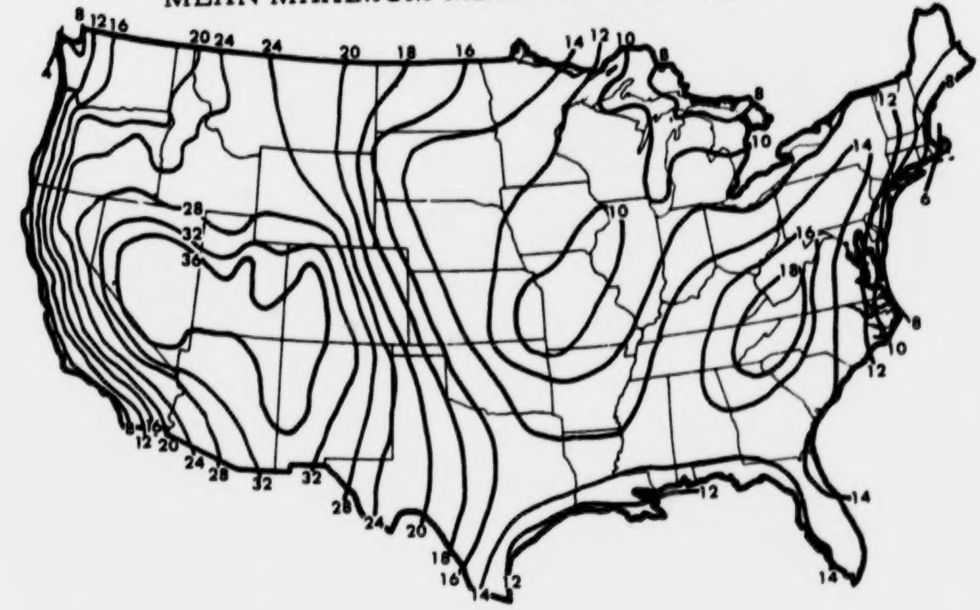
Figure 8

MEAN MAXIMUM MIXING DEPTHS, JUNE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Source: George C. Holzworth, "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XCII (May, 1964).

Figure 9

MEAN MAXIMUM MIXING DEPTHS, JULY

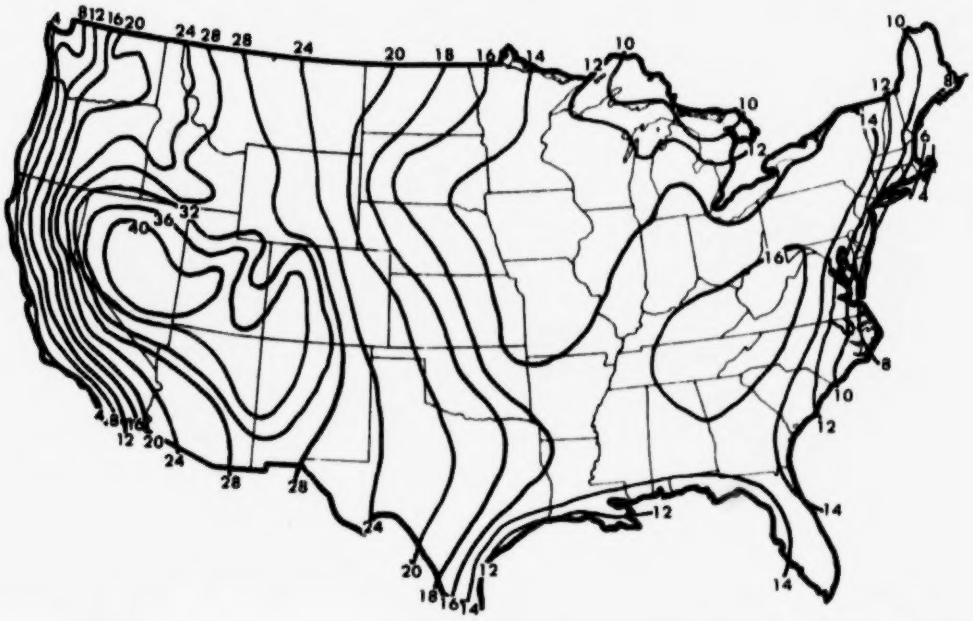
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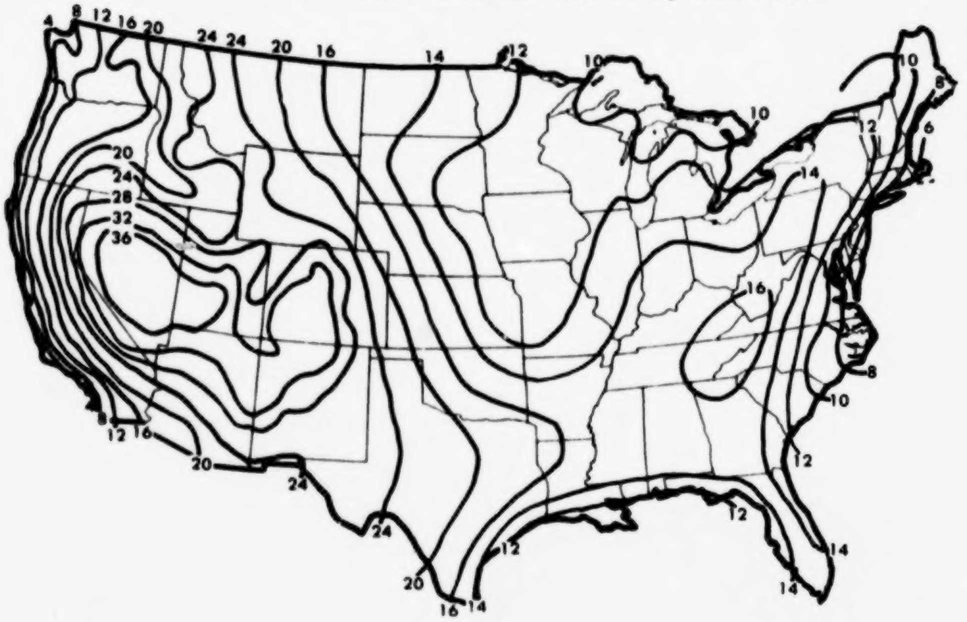
Figure 10

MEAN MAXIMUM MIXING DEPTHS, AUGUST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Source: George C. Holzworth, "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XCII (May, 1964).

Figure 11

MEAN MAXIMUM MIXING DEPTHS, SEPTEMBER

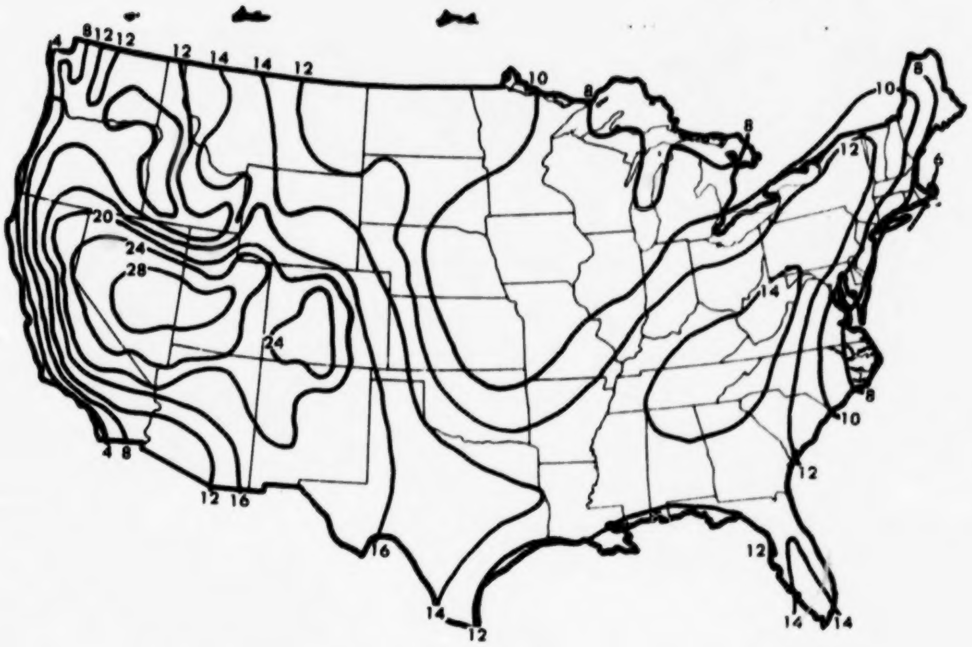
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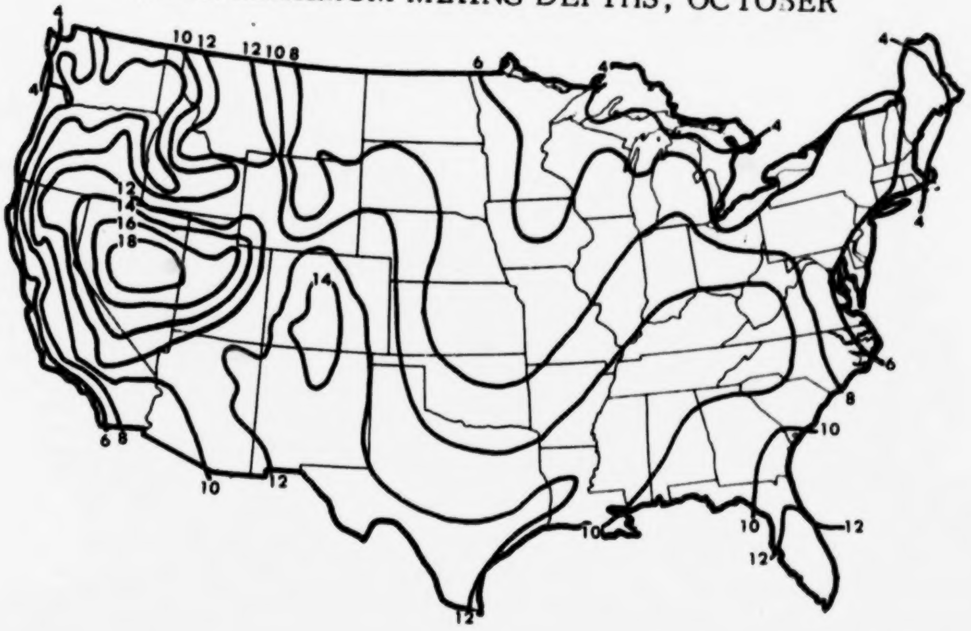
Figure 12

MEAN MAXIMUM MIXING DEPTHS, OCTOBER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Source: George C. Holzworth, "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XCII (May, 1964).

Figure 13

MEAN MAXIMUM MIXING DEPTHS, NOVEMBER

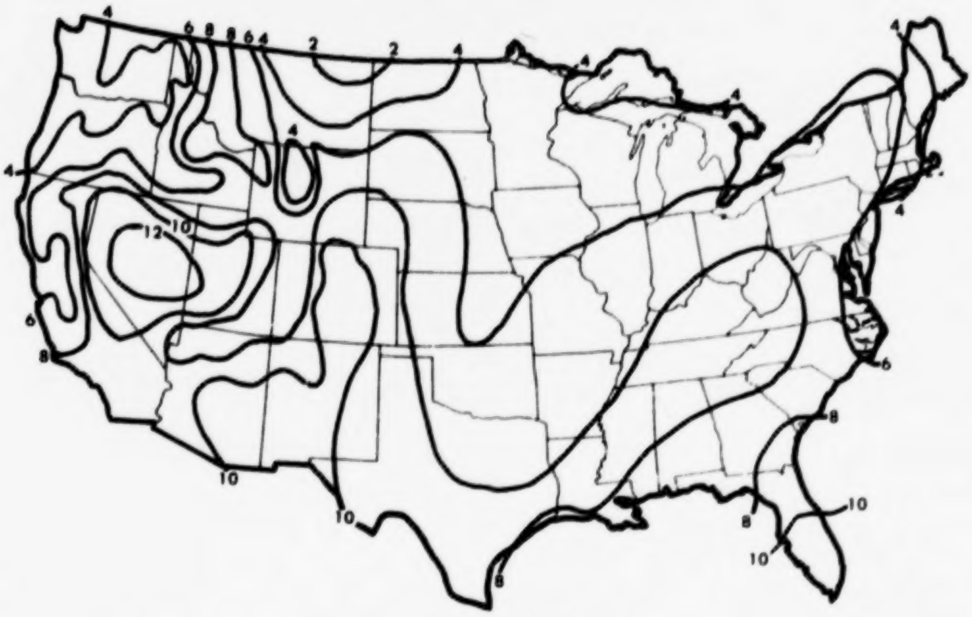
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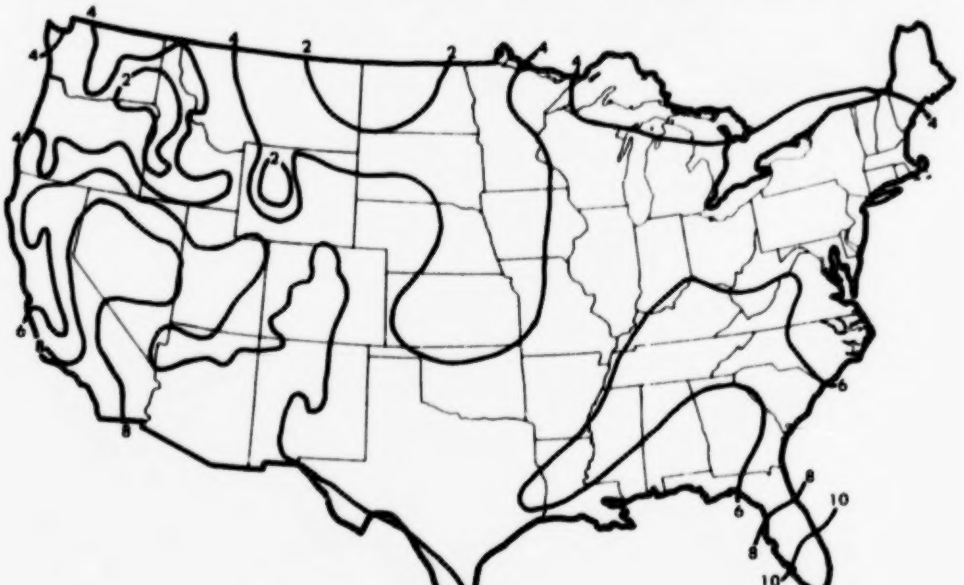
Figure 14

MEAN MAXIMUM MIXING DEPTHS, DECEMBER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Source: George C. Holzworth, "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XCII (May, 1964).

Wind Characteristics

Estimates of mean hourly wind velocity at an elevation of 50 feet are presented in Figures 15 through 18 for representative months for each of the four seasons. Most values fall within the 5 to 15 miles per hour range, with highest velocities occurring along the coasts and across the Great Plains, and lowest velocities occurring in the general vicinity of the Appalachian and Rocky Mountain Ranges. The persistence of surface wind speeds of less than about 7 miles per hour have often been found detrimental to the processes by which pollutants are diluted in the atmosphere.[6] Percent frequency of nighttime winds of less than 7 miles per hour is indicated in Figure 19 for each season and for the year as a whole. Low nighttime winds are observed to be most common in Rocky Mountain and Appalachian areas, and least common along the coasts and across the Great Plains.

As was the case for inversion data, the wind speeds shown are mostly the results of airport measurements. However, studies indicate that such data can be quantitatively useful to estimate air flow over adjacent cities. For example, studies conducted at Nashville, Tennessee, indicate that urban wind velocities average about 60 to 70 percent of those measured at a nearby airport.[7]

Figure 15

HOURLY MEAN WIND SPEED ESTIMATES FOR JANUARY, CORRECTED TO 50 FEET ABOVE GROUND (Miles Per Hour)

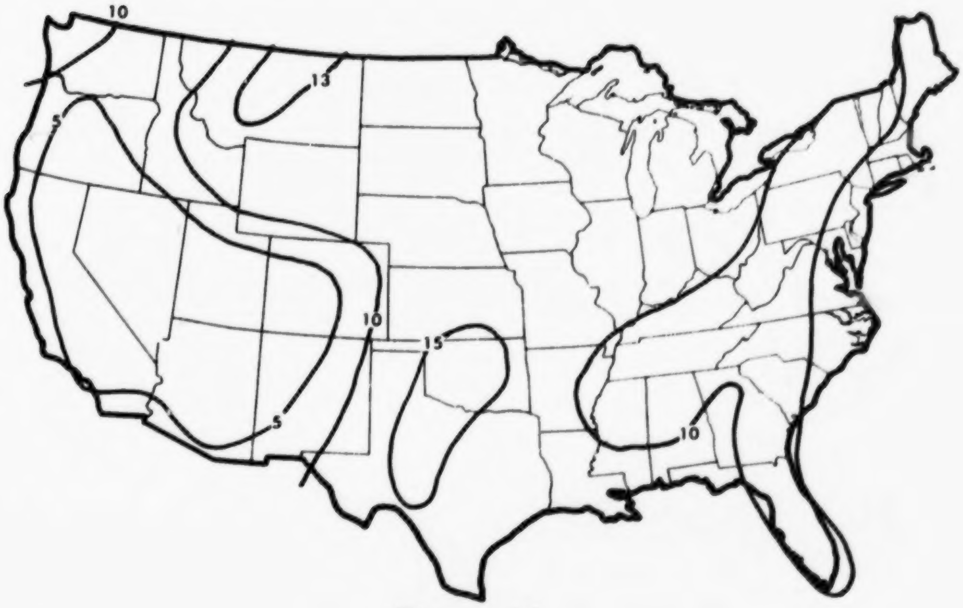
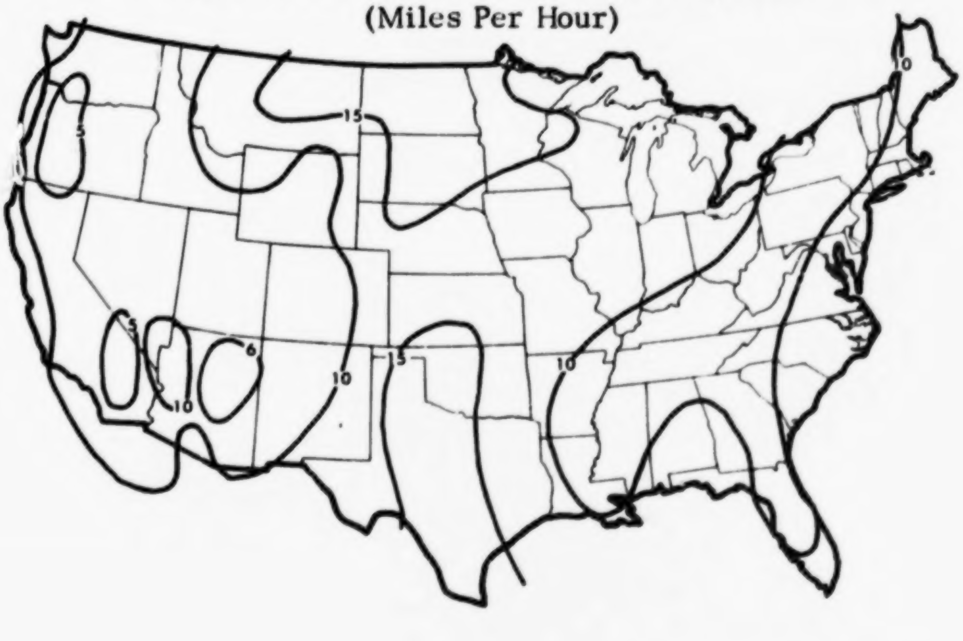


Figure 16

HOURLY MEAN WIND SPEED ESTIMATES FOR APRIL, CORRECTED TO 50 FEET ABOVE GROUND (Miles Per Hour)



Source: U.S. Air Force, Handbook of Geophysics and Space Environments, ed. Shea L. Valley (Cambridge, Massachusetts: Air Force Cambridge Research Laboratories, Office of Aerospace Research, 1965).

Figure 17

HOURLY MEAN WIND SPEED ESTIMATES FOR JULY, CORRECTED TO 50 FEET ABOVE GROUND (Miles Per Hour)

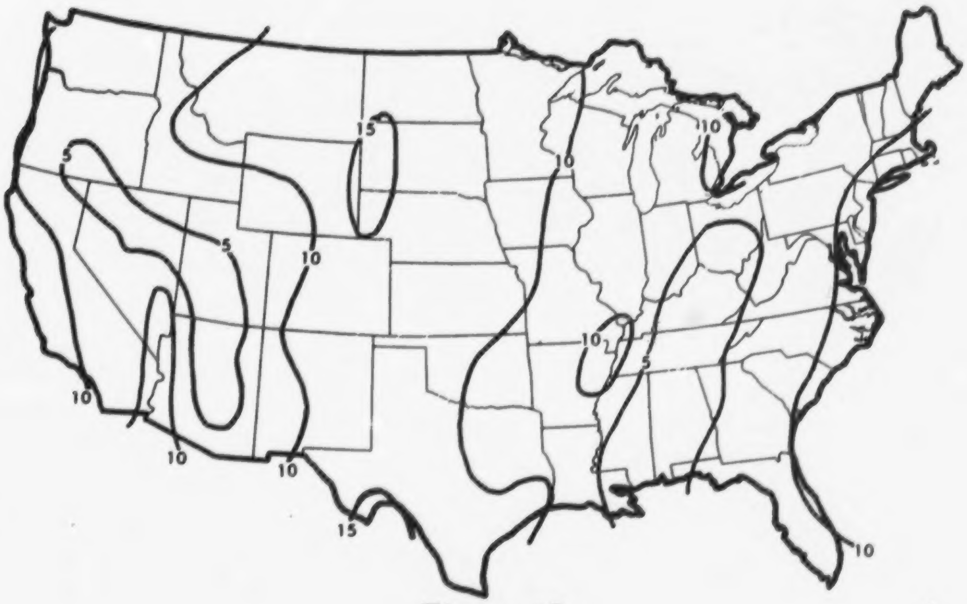

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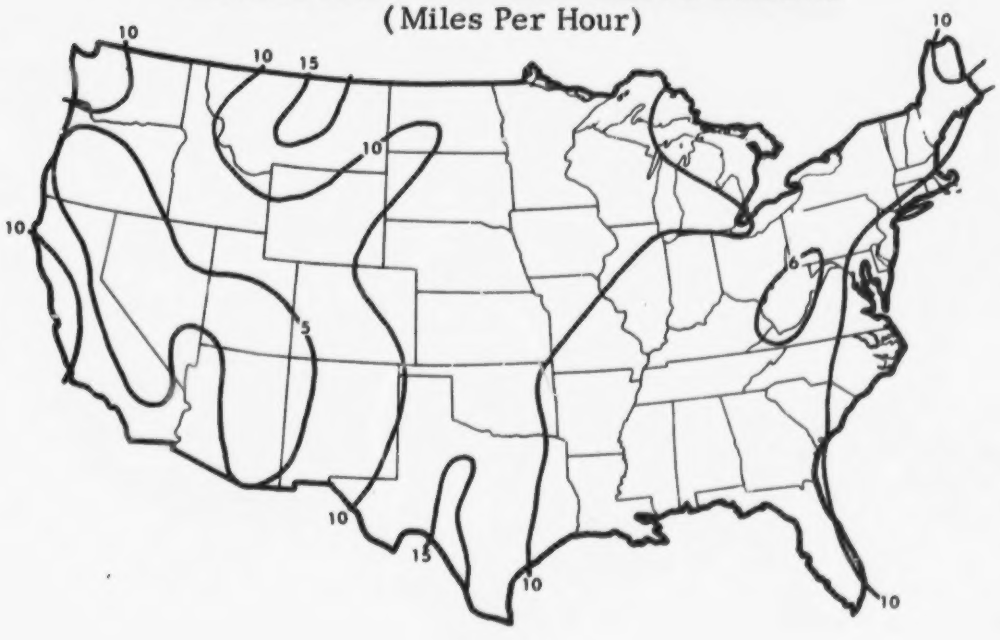
Figure 18

HOURLY MEAN WIND SPEED ESTIMATES FOR OCTOBER CORRECTED TO 50 FEET ABOVE GROUND (Miles Per Hour)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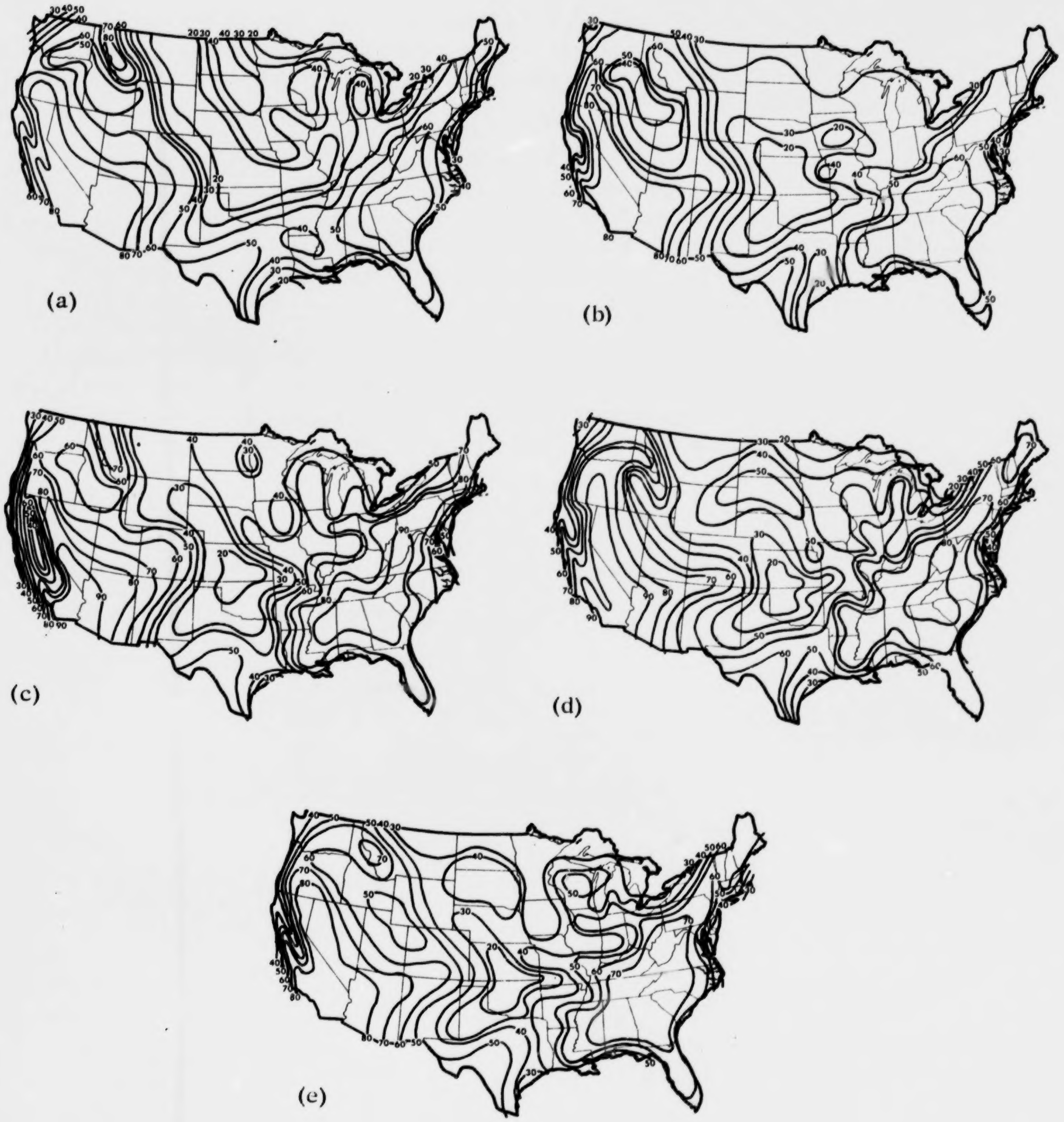
Source: U.S. Air Force, Handbook of Geophysics and Space Environments, ed. Shea L. Valley (Cambridge, Massachusetts: Air Force Cambridge Research Laboratories, Office of Aerospace Research, 1965).

Figure 19

PERCENT FREQUENCY OF NIGHTTIME WIND SPEED
≤ 7 Miles Per Hour For:
(a) Winter, (b) Spring, (c) Summer, (d) Fall, (e) Annual



Source: C. R. Hosler, "Low-Level Inversion Frequency in the Contiguous United States," Monthly Weather Review, LXXXIX (November, 1961).

Weather Bureau Air Pollution Potential Warnings

The atmospheric variables identified in preceding sections as being major causes of impaired atmospheric dilution capacity form the basis of the U.S. Weather Bureau Air Pollution Potential warning system. The criterion used for the issuance of warnings is a prediction of 36 hours or more continuous duration of simultaneous low-level inversion conditions, and low mean wind velocities within the mixing depth.[8] These warnings represent the synthesis of the effects of all the atmospheric variables found to have bearing on the dilution capacity of the atmosphere and, thus, have unique value to this study.

Unfortunately, records of air pollution potential warnings are not a part of the routinely tabulated data available from the Weather Bureau. However, a graphical summary has been prepared which, although covering only a limited span of time, provides a useful picture of the relative atmospheric vulnerability of areas of the United States to serious odor problems. This summary is presented in Figure 20.

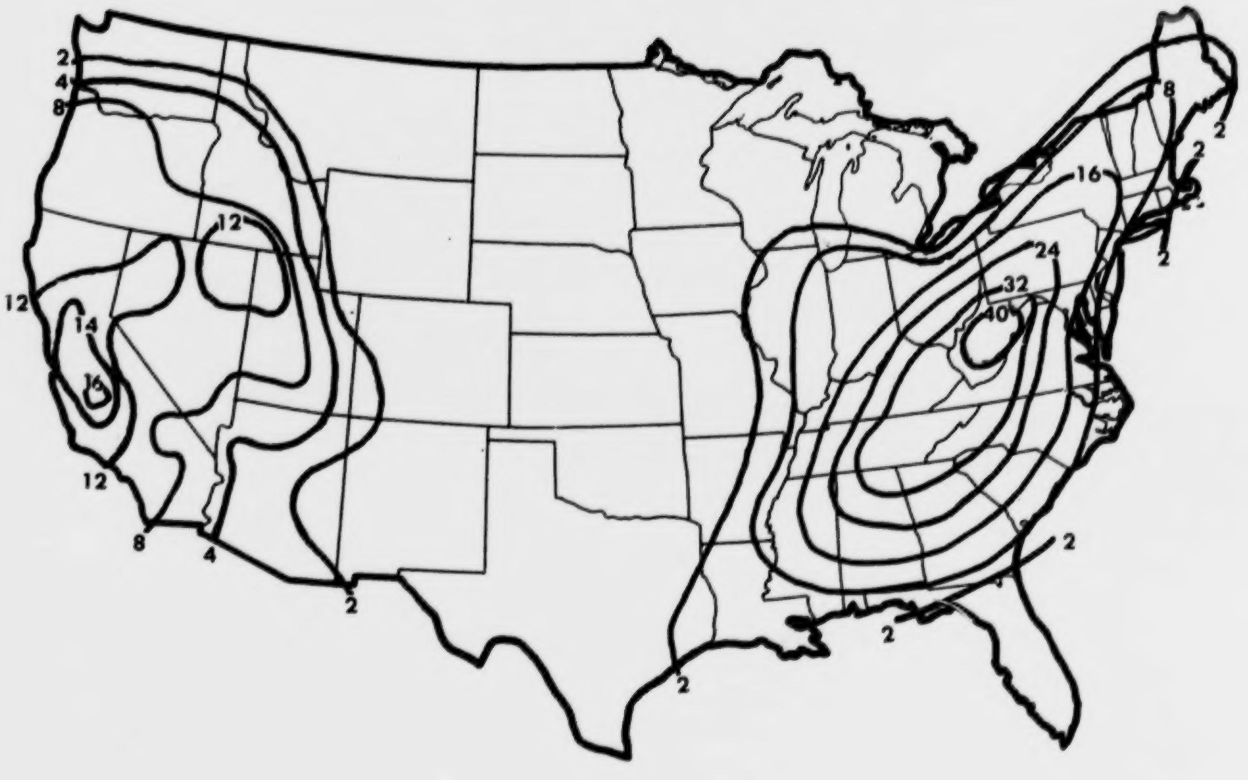
The pattern which is shown in Figure 20 is similar to that observed for inversion and wind data considered separately and reinforces the observation that the Pacific Coast and the Rocky and Appalachian Mountain areas are the parts of the United States most vulnerable to odor problems from a meteorological standpoint.

Figure 20

AIR POLLUTION POTENTIAL WARNING PERIODS
FOR YEARS INDICATED

Western United States:
Five warnings issued from
October, 1963 to June, 1964

Eastern United States:
Forty-one warnings issued from
August, 1960 to June, 1964



Legend

n ▬ Total number of periods with predicted 36 hours or more continuous duration of simultaneous low-level inversion conditions and low mean wind velocities within the mixing depth, where n is 2, 4, 8, 12, 14, 16, 24, 32 or 40.

Source: George C. Holzworth, "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XCII (May, 1964).

Topography

Local topography can modify significantly the patterns of atmospheric stability and wind characteristics presented above. Because of the localized nature of such effects, no graphical summary for the entire country is feasible; however, some principles may be stated for application to specific areas:

(1) Inversion frequencies are normally lower for mountain slopes and summits than for adjacent valleys.[9]

(2) Valleys tend to channel winds parallel to their axes.[10]

(3) Differential heating phenomena can cause diurnal variations in wind direction, with up-slope winds in daytime and down-slope down-valley winds at night.[11]

(4) Wind velocities are often higher on ridgelines and passes because of volumetric constriction of the moving body of air.[11]

(5) Differential rates of heating and cooling of adjacent land and water surfaces can lead to daytime landward winds and seaward breezes at night.[11]

Atmospheric stability, wind characteristics, and topography are all important factors affecting the perception of odors as a problem. Geographical areas in the United States that exhibit the least favorable characteristics for odor dispersion are the Appalachians, the Rocky Mountains, and the Pacific Coast. The Pacific Coast is included since ocean-induced inversions above 500 feet are semi-permanent during spring, summer, and fall.

Notes

1. Interview with Mr. Benjamin R. Ford, California State Department of Public Health, Bureau of Air Sanitation.

2. R. A. McCormick, "Air Pollution Climatology," Air Pollution, Vol. I, ed. A. C. Stern (2nd ed.; New York: Academic Press, 1968), 275-320.

3. C. R. Hosler, "Low-Level Inversion Frequency in the Contiguous United States," Monthly Weather Review, LXXXIX (November, 1961), 319-339.

4. George C. Holzworth, "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XCII (May, 1964), 235-242.

5. Hosler, op. cit.

6. McCormick, op. cit., 288-294.

7. Ibid., p. 277.

8. U.S. Weather Bureau, Research Progress and Plans of the U.S. Weather Bureau Fiscal Year 1964, 1965, pp. 93-95.

9. McCormick, op. cit., 288-294.

10. H. A. Panofsky and B. Prasad, "The Effect of Meteorological Factors On Air Pollution in a Narrow Valley," Journal of Applied Meteorology, VI (June, 1967), pp. 493-499.

11. R. C. Wanta, "Meteorology and Air Pollution," Air Pollution, Vol. I, ed. A. C. Stern (2nd ed.; New York: Academic Press, 1968), pp. 187-226.

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Boettger, C. M. "Air Pollution Potential East of the Rocky Mountains: Fall 1959," American Meteorological Society Bulletin, XLII (September, 1961), 615-630.

California, Department of Public Health. Interview with Mr. Benjamin R. Ford, Bureau of Air Sanitation.

Environmental Data Service, Silver Springs, Maryland. Correspondence with Mr. R. W. Schloemer, Director, Office of Data Information.

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CHAPTER V

CONCENTRATIONS OF POPULATION AND COMBINATION OF POTENTIAL ODOR PROBLEM FACTORS

As stated in the previous chapter, the presence of an odor problem is dependent upon the existence of an odorant source (or sources) and a transport mechanism that would convey these odorants to an odor receptor population. But the problem, itself, emerges from the reaction of the population affected. Thus, the extent of the problem is dependent upon the size of the population affected.

Based on the above, the initial step toward an assessment of the national odor problem was undertaken. The distribution of population in the United States was examined and areas of concentrated population were located. Results of the preceding chapters were then used to determine which of these areas were coincident with areas of industrial odor producing potential and within regions of odorant supporting atmosphere. This chapter describes these activities.

METHOD OF LOCATING AND RANKING CONCENTRATIONS OF POPULATION

To achieve graphical consistency with the industrial odorant source information described in Chapter III, it was necessary to locate a source of population data based on three-digit postal zip code areas so that areas with both large population and high industrial odor producing potential could be easily identified. An exhaustive search proved that recent governmental sub-state population estimates are available only by Standard Metropolitan Statistical Area and, in some cases, by county and city. Few, if any, of these regions closely represent the areas of the three-digit zip code system. The search did, however, result in the discovery of a useful commercial source — the Rand McNally Commercial Atlas & Marketing Guide.[1]

Aside from a multitude of maps, the Commercial Atlas & Marketing Guide contains economic, demographic, and marketing information on several types of geographic subdivisions. Most important for this investigation, population estimates for 1969 were provided on a three-digit zip code basis.[2]

Size of Population in Postal Zip Code Areas

For purposes of this study, a "metropolitan area" is defined as a city (or contiguous cities) to which the Post Office Department has assigned a unique three-digit zip code number (or numbers) plus the surrounding three-digit zip code area (or areas). This definition reflects the combinations of three-digit zip code areas for which population data is available in the Commercial Atlas & Marketing Guide.

Applying this definition to a ranking of the number of persons in each three-digit zip code area supports common knowledge that the population is concentrated in the metropolitan areas of the United States. Table I presents a ranking of the fifty metropolitan areas having the largest number of persons. It was determined that forty-nine percent of estimated national population of 201 million persons (as of January 1, 1969) are located in these fifty metropolitan areas.[3] The three-digit zip codes included in each of the metropolitan areas of Table I are listed in Appendix B.

Table I

FIFTY METROPOLITAN AREAS IN THE UNITED STATES HAVING THE LARGEST NUMBER OF PERSONS (1969 Estimates)

Rank	Metropolitan Area	No. of Persons (in thousands)	Rank	Metropolitan Area	No. of Persons (in thousands)
1	New York, NY	8,946	26	Indianapolis, IN	1,295
2	Los Angeles, CA	7,468	27	Columbus, OH	1,246
3	Chicago, IL	7,057	28	Seattle, WA	1,186
4	Philadelphia, PA-Camden, NJ	5,177	29	Tampa, FL	1,171
5	Detroit, MI	4,693	30	Prince Georges, MD	1,137
6	Newark, NJ	4,005	31	New Orleans, LA	1,117
7	San Francisco-Oakland, CA	3,281	32	San Antonio, TX	1,116
8	Boston, MA	3,260	33	Denver, CO	1,115
9	St. Louis, MO-East St. Louis, IL	2,490	34	Santa Ana, CA	1,100
10	Cleveland, OH	2,368	35	Dayton, OH	1,073
11	Houston, TX	2,154	36	New Haven, CT	1,067
12	Minneapolis-St. Paul, MN	1,998	37	Greensboro, NC	1,066
13	Milwaukee, WI	1,957	38	Phoenix, AZ	1,058
14	Pittsburgh, PA	1,939	39	Norfolk, VA	1,051
15	Baltimore, MD	1,924	40	San Jose, CA	1,004
16	Atlanta, GA	1,893	41	Portland, OR	1,001
17	Washington, DC-Arlington, VA	1,743	42	Rochester, NY	968
18	Miami, FL	1,703	43	White Plains, NY	934
19	Kansas City, KS-Kansas City, MO	1,547	44	Charlotte, NC	934
20	Dallas, TX	1,535	45	Birmingham, AL	932
21	Buffalo, NY	1,490	46	Nashville, TN	918
22	Cincinnati, OH	1,441	47	Memphis, TN	907
23	Hicksville, NY	1,402	48	Louisville, KY	898
24	Providence, RI	1,327	49	Sacramento, CA	884
25	San Diego, CA	1,300	50	Hartford, CT	869

Source: Rand McNally & Company, Commercial Atlas & Marketing Guide, 1969.

It is acknowledged that the size of population in each three-digit zip code area is not an optimum measure of concentration because of vast differences in the number of square miles and a lack of information as to the distribution of population within each three-digit area. These deficiencies extend to the metropolitan areas, which are defined above as combinations of certain three-digit areas. As an example of the differences in land area, the number of square miles in each of the fifty metropolitan areas of Table I ranges from 469 square miles for New York, NY, to 28,903 square miles for Phoenix, AZ. (That the size of the Phoenix metropolitan area approaches an extreme can be seen by noting that the median of this range is 4,214 square miles and that only three of 155 metropolitan areas in the Unites States are larger.)

Density of Population in Postal Zip Code Areas

To compensate for these deficiencies it was decided to compute the density of population of each metropolitan area in the United States. The decision was based on the premise that odor problems would be more extensive in a metropolitan area supporting a large and compact, rather than smaller or less dense, population. However, an additional difficulty was encountered using the three-digit zip code system. An examination of the geographic features of the metropolitan areas revealed that some are extremely urban in character, while many others are only partly urban. Because of the presence of rural and vacant land outside a metropolitan area's primary population center, its overall density could be greatly diluted. Such a dilution effect may result in an unwarranted conclusion that a more urbanized area contains greater concentration of population than the partly urbanized areas. As an example of the dilution effect, note that Phoenix, AZ, with a density of population of 1,058 thousand persons/28,903 square miles, or 37 persons per square mile, was estimated to be at least seventy percent open range, desert, and mountains.

For increased comparability of population density, it was decided to abandon the use of three-digit zip code data for population and land area information. An ideal basis for such data would be combinations of the smaller five-digit zip code areas. But it is anticipated that five-digit zip code data will not be available until 1972, at which time the Bureau of the Census will publish 1970 population statistics for each of 38,000 possible five-digit zip code areas in the United States. It is expected that this information, together with currently available five-digit area data on the odor producing potential of industrial odorant sources, will provide considerable accuracy in locating potential odor problems within metropolitan areas.

Density of Population in SMSA Principal Counties

In lieu of three-digit zip code areas, Bureau of the Census information was found to provide 1968 estimates of population based on Standard Metropolitan Statistical Areas (SMSA's).[5] Although SMSA's also differ greatly in land area, each SMSA contains a principal county (or, in a few cases, an independent city) which is urban in character. Estimates of the land area included in each principal county were obtained from the Rand McNally Commercial Atlas & Marketing Guide. Using this data, the population density of each SMSA principal county in the United States was calculated. Table II presents a ranking of the principal counties of fifty Standard Metropolitan Statistical Areas having the highest densities of population.

Table II

PRINCIPAL COUNTIES OF FIFTY STANDARD METROPOLITAN STATISTICAL AREAS IN THE UNITED STATES HAVING THE HIGHEST DENSITIES OF POPULATION

Rank	Standard Metropolitan Statistical Area	Principal County(s)	No. of Persons Per Sq. Mile	Rank	Standard Metropolitan Statistical Area	Principal County(s)	No. of Persons Per Sq. Mile
1	New York, NY	Bronx, Kings, Manhattan, Queens, Richmond	26,547	26	Columbus, OH	Franklin	1,467
2	Philadelphia, PA	Philadelphia	15,755	27	Dallas, TX	Dallas	1,417
3	Washington, DC	District of Columbia	13,245	28	Toledo, OH	Lucas	1,399
4	Jersey City, NJ	Hudson	13,078	29	Akron, OH	Summit	1,356
5	Boston, MA	Suffolk	12,278	30	Dayton, OH	Montgomery	1,288
6	Baltimore, MD	*	11,533	31	Portland, OR	Multnomah	1,270
7	St. Louis, MO	*	11,247	32	Atlanta, GA	DeKalb-Fulton	1,255
8	Newark, NJ	Essex	7,498	33	Bridgeport, CT	Fairfield	1,498
9	Denver, CO	Denver	7,251	34	New Haven, CT	New Haven	1,202
10	Norfolk-Portsmouth, VA	*	5,930	35	Providence-Pawtucket-Warwick, RI	Kent-Providence	1,197
11	Richmond, VA	*	5,784	36	Omaha, NB	Douglas	1,135
12	Chicago, IL	Cook	5,683	37	Hartford, CT	Hartford	1,085
13	Detroit, MI	Wayne	4,430	38	Honolulu, HI	Honolulu	1,055
14	Milwaukee, WI	Milwaukee	4,355	39	Buffalo, NY	Erie	1,022
15	Cleveland, OH	Cuyahoga	3,820	40	Gary-Hammond-East Chicago, IN	Lake	1,005
16	New Orleans, LA	Orleans	3,095	41	Rochester, NY	Monroe	994
17	Paterson-Clifton-Passaic, NJ	Passaic	2,407	42	Memphis, TN	Shelby	950
18	Cincinnati, OH	Hamilton	2,235	43	Houston, TX	Harris	946
19	San Francisco-Oakland, CA	San Francisco-Alameda	2,233	44	Wilmington, DE	New Castle	852
20	Pittsburgh, PA	Allegheny	2,198	45	Nashville, TN	Davidson	846
21	Indianapolis, IN	Marion	1,917	46	San Jose, CA	Santa Clara	758
22	Minneapolis-St. Paul, MN	Hennepin-Ramsey	1,862	47	Kansas City, KS - Kansas City, MO	Clay-Jackson	742
23	Louisville, KY	Jefferson	1,800	48	Fort Worth, TX	Tarrant	734
24	Los Angeles, CA	Los Angeles	1,686	49	Tampa, FL	Hillsborough-Pinellas	709
25	Anaheim-Santa Ana-Garden Grove, CA	Orange	1,612	50	Oklahoma City, OK	Oklahoma	705

* City(s) independent of any county.

Source: U.S. Bureau of the Census, Current Population Reports, Series P-25, No. 432, October 3, 1969, and Rand McNally & Company, Commercial Atlas & Marketing Guide, 1969.

COINCIDENCE OF POTENTIAL ODOR PROBLEM FACTORS

As an initial step toward an assessment of the national odor problem, it was necessary to determine which three-digit zip code areas ranked high in both size of population and industrial odor producing potential and were located within regions of odorant supporting atmosphere. This step also provided basic criteria for the selection of seven metropolitan areas in which the extent of actual odor problems was investigated.

Figure 1 (fold-out) illustrates a quartile ranking of size of population in all three-digit zip code areas (termed "Sectional Areas" by the Post Office Department) in the United States.[6] Note that each three-digit area is uniformly color-coded to relate to four ranges of population. The uniformity of color is not meant to indicate uniformity in concentration of population throughout each area. Rather, it reflects the fact that presently there are no more accurate means of locating concentrations of population using the zip code system.

As could be expected, the three-digit areas of the upper quartile (328,000 persons or more) include many state capitals and other principal cities.

Figure 2 (fold-out) gives a quartile ranking of the odor producing potential of industrial odorant sources in all three-digit zip code areas. In this figure, each three-digit area is uniformly color-coded to relate to four ranges of linear-modified weighted values. (As described in Chapter III, the linear-modified weighted value in each three-digit zip code area is the summation of the products of the numbers of industrial plants in any of forty-eight SIC classifications, the applied odor characteristic coefficient, and relative output.)[7] Again, the uniformity of color is not meant to indicate uniformity in concentration of groupings of potential odorant sources throughout each area. Instead, it is used for comparison with the size of population rankings of Figure 1.

The coincidence of the upper quartiles of both figures, especially in the industrial centers of the United States, is the result of two basic factors: Since industrial centers typically contain a broad representation of industries known to be potential sources of odorant emission, the overall odor producing potential is high; and since industrial centers support a large labor force, the total population is high.

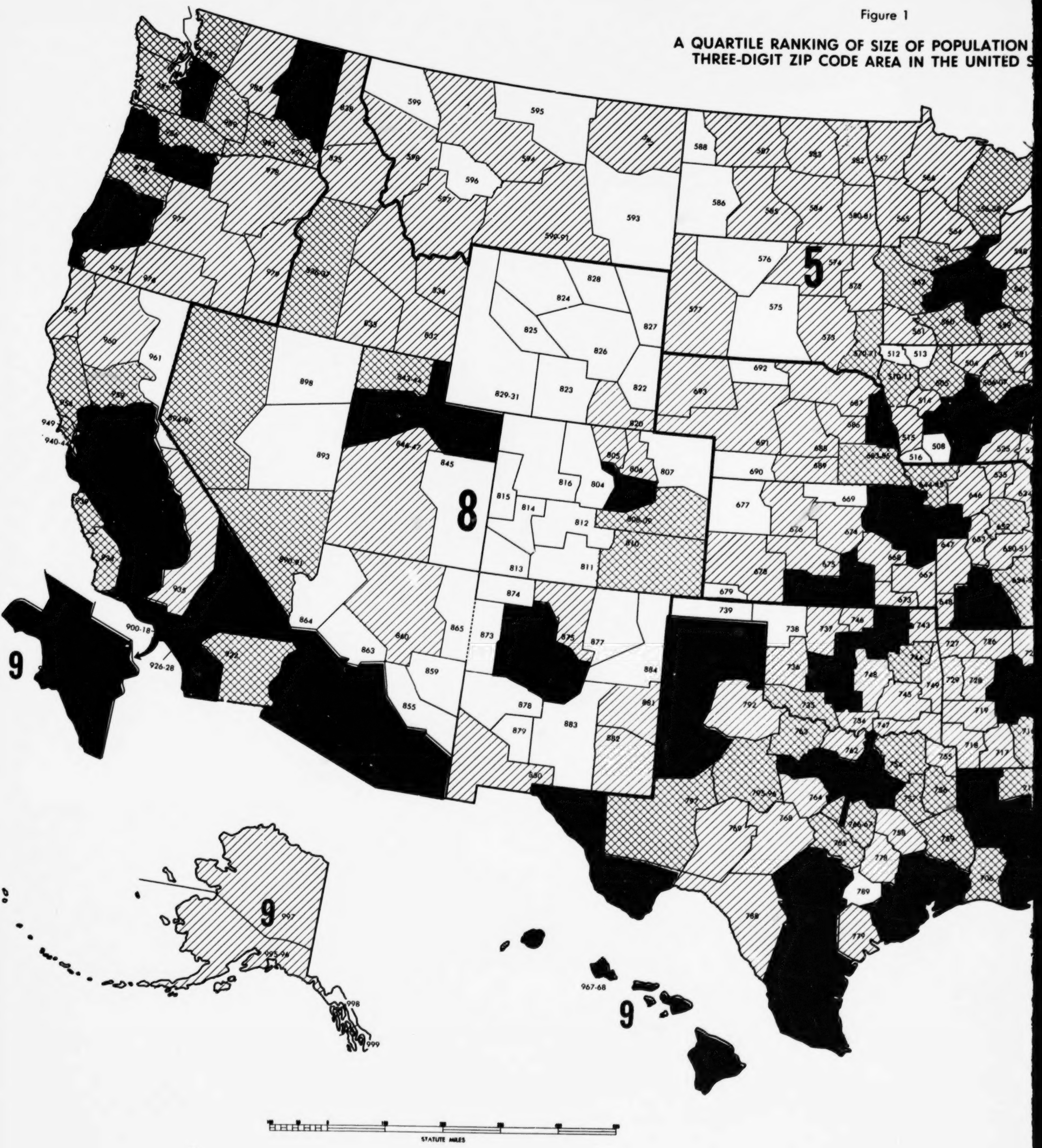
For comparison with the preceding figures, the graphical summary of the relative atmospheric vulnerability of areas in the United States to serious odor problems (Chapter IV, Figure 20) is reproduced in Figure 3 (fold-out) on a three-digit zip code map of the United States. A composite map of this summary of air pollution warning periods and the upper quartiles of Figures 1 and 2 is presented in Chapter X with an assessment of the national odor problem. A listing of the number and name of the principal transportation hub (termed "Sectional Center") in each three-digit zip code area appearing in these figures is provided in Appendix C.

It is emphasized that the development of this set of potential odor problem factors was for the purpose of problem identification on a metropolitan area scale. The availability of additional data (especially population data on a five-digit zip code basis) is required before potential odor problems can be accurately identified in terms of neighborhoods.

Seven metropolitan areas were selected from those judged as odor problem areas to determine the extent of actual odor problems in different parts of the nation. The criteria used in selecting these metropolitan areas and the investigations conducted in each are discussed in the following four chapters.

Figure 1

A QUARTILE RANKING OF SIZE OF POPULATION THREE-DIGIT ZIP CODE AREA IN THE UNITED S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510-11
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STATUTE MILES

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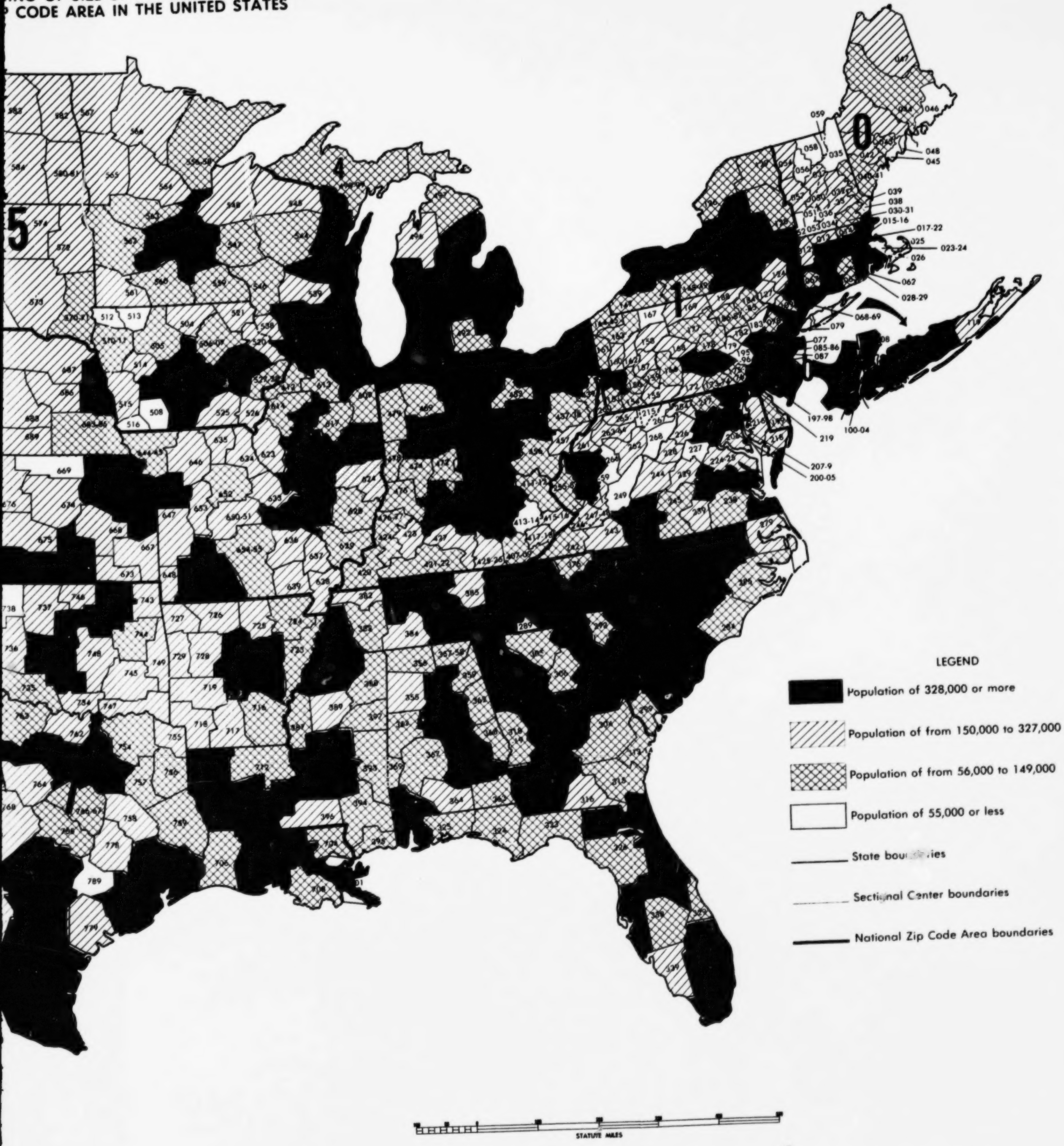
Figure 1

KING OF SIZE OF POPULATION IN EACH P CODE AREA IN THE UNITED STATES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017-22
025
023-24
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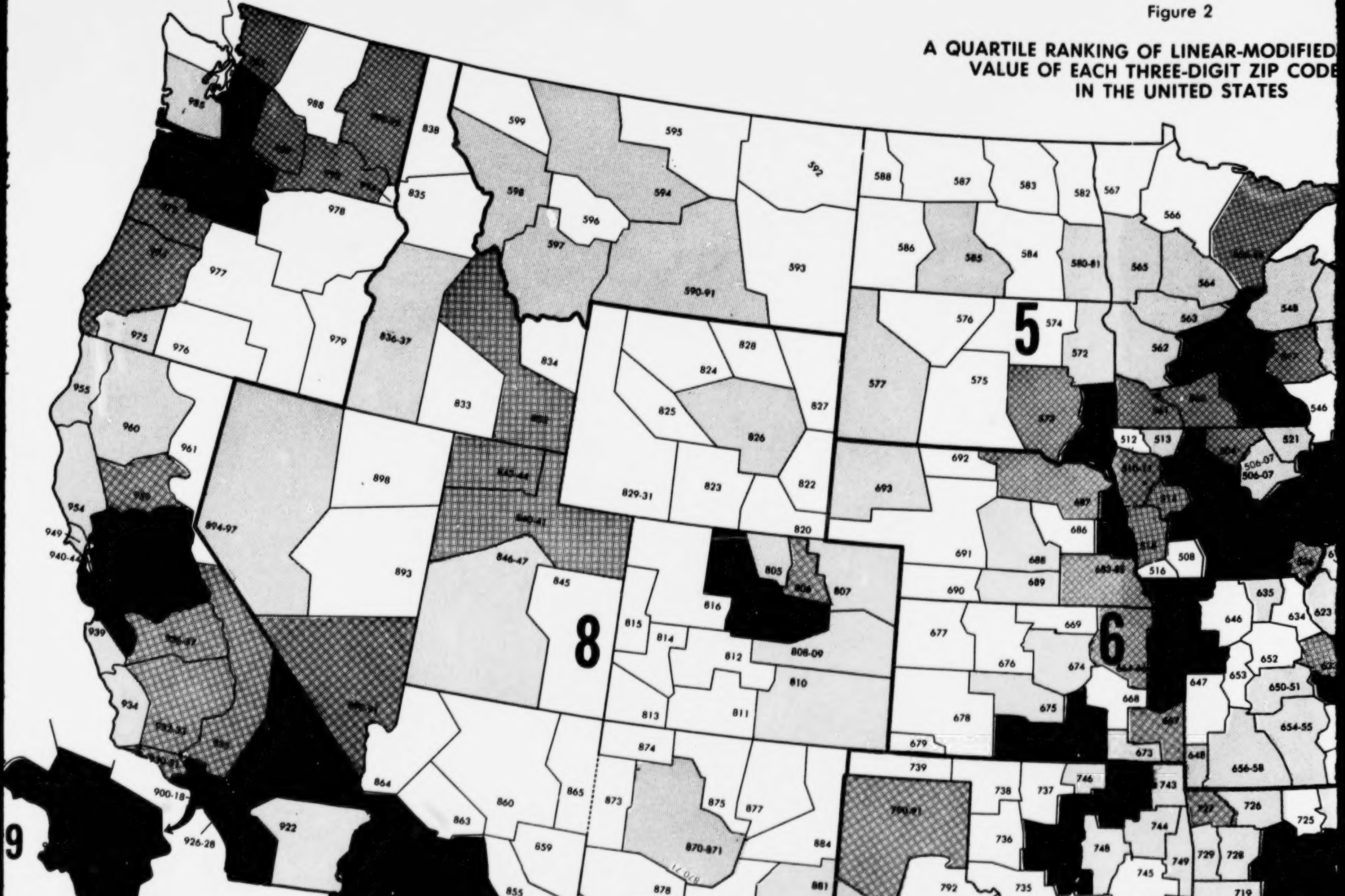
062
028-29
068-69
079
077
085-86
087
197-98
219
100-04
207-9
200-05
LEGEND
Population of 328,000 or more
Population of from 150,000 to 327,000
Population of from 56,000 to 149,000
Population of 55,000 or less
State boundaries
Sectional Center boundaries
National Zip Code Area boundaries
STATUTE MILES

B

Figure 2

A QUARTILE RANKING OF LINEAR-MODIFIED
VALUE OF EACH THREE-DIGIT ZIP CODE
IN THE UNITED STATES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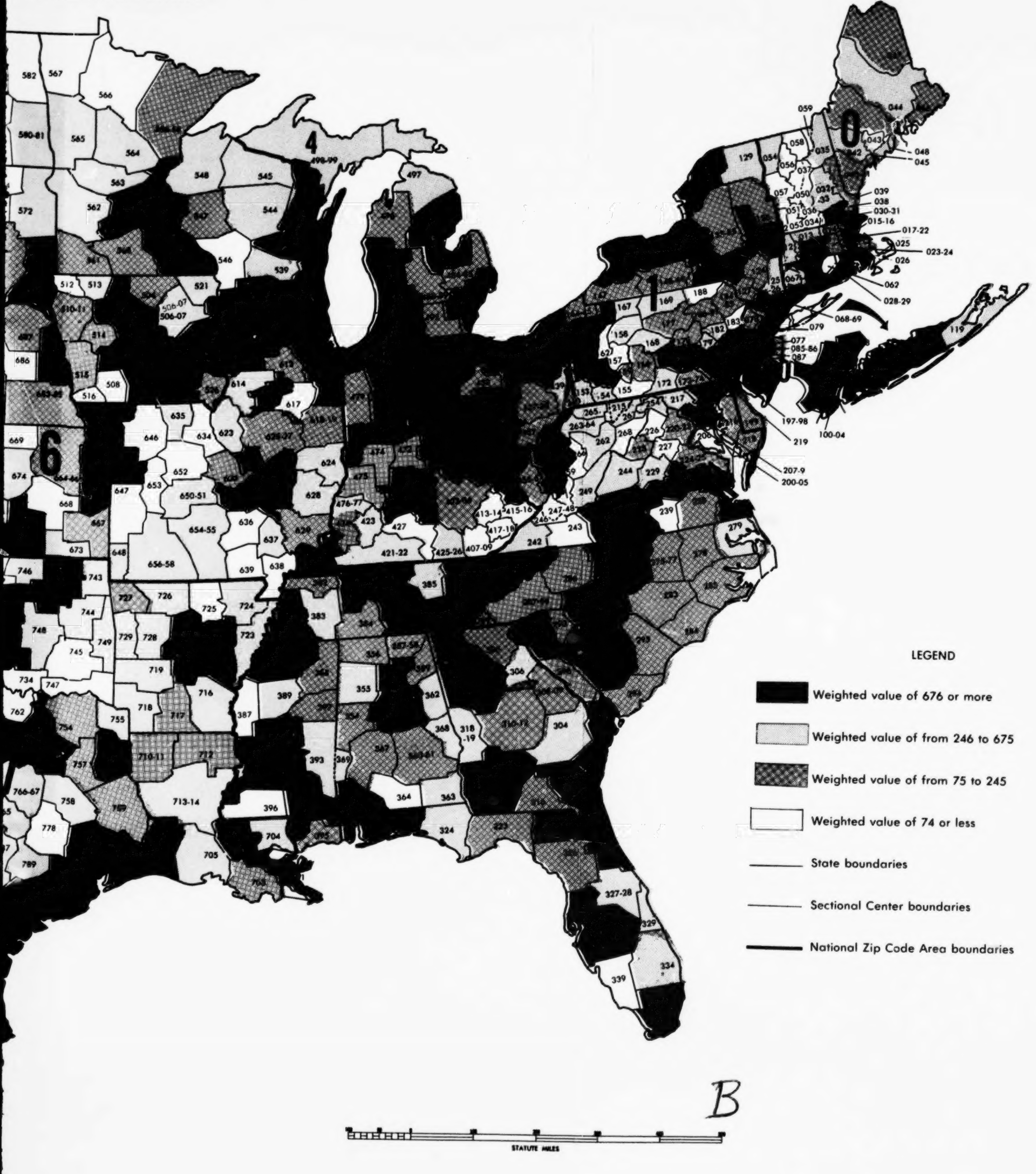
STATUTE MILES

Figure 2

ANKING OF LINEAR-MODIFIED WEIGHTED
F EACH THREE-DIGIT ZIP CODE AREA
IN THE UNITED STATES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015-16
017-22
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023-24
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062
028-29
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068-69
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085-86
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100-04
197-98
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207-9
200-05
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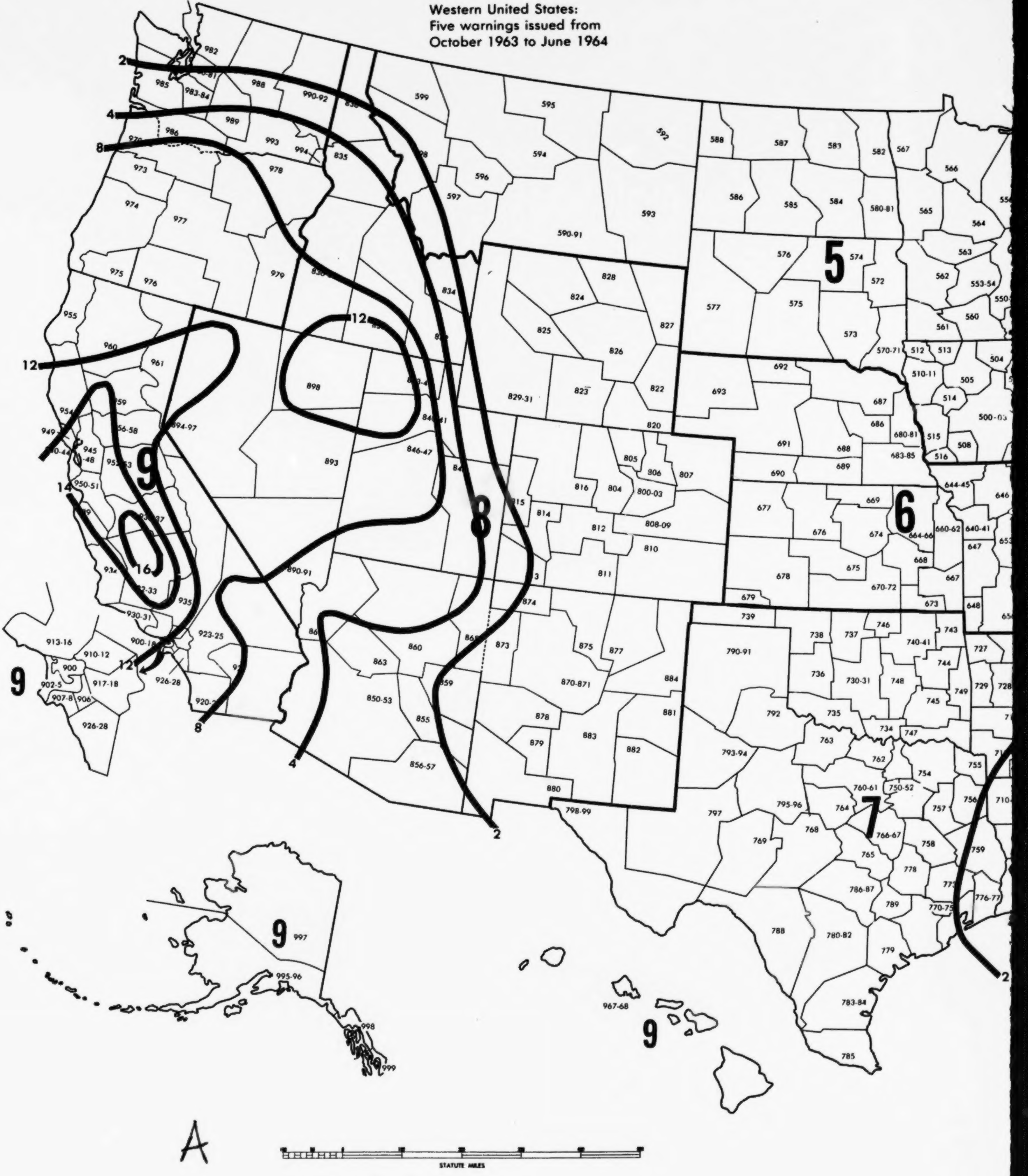
217
265
215
263-64
262
268
226
227
244
229
249
LEGEND
Weighted value of 676 or more
Weighted value of from 246 to 675
Weighted value of from 75 to 245
Weighted value of 74 or less
State boundaries
Sectional Center boundaries
National Zip Code Area boundaries
STATUTE MILES
B

Figure

AIR POLLUTION POTENTI
FOR YEARS I



Western United States:
Five warnings issued from
October 1963 to June 1964

2
4
8
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16
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STATUTE MILES

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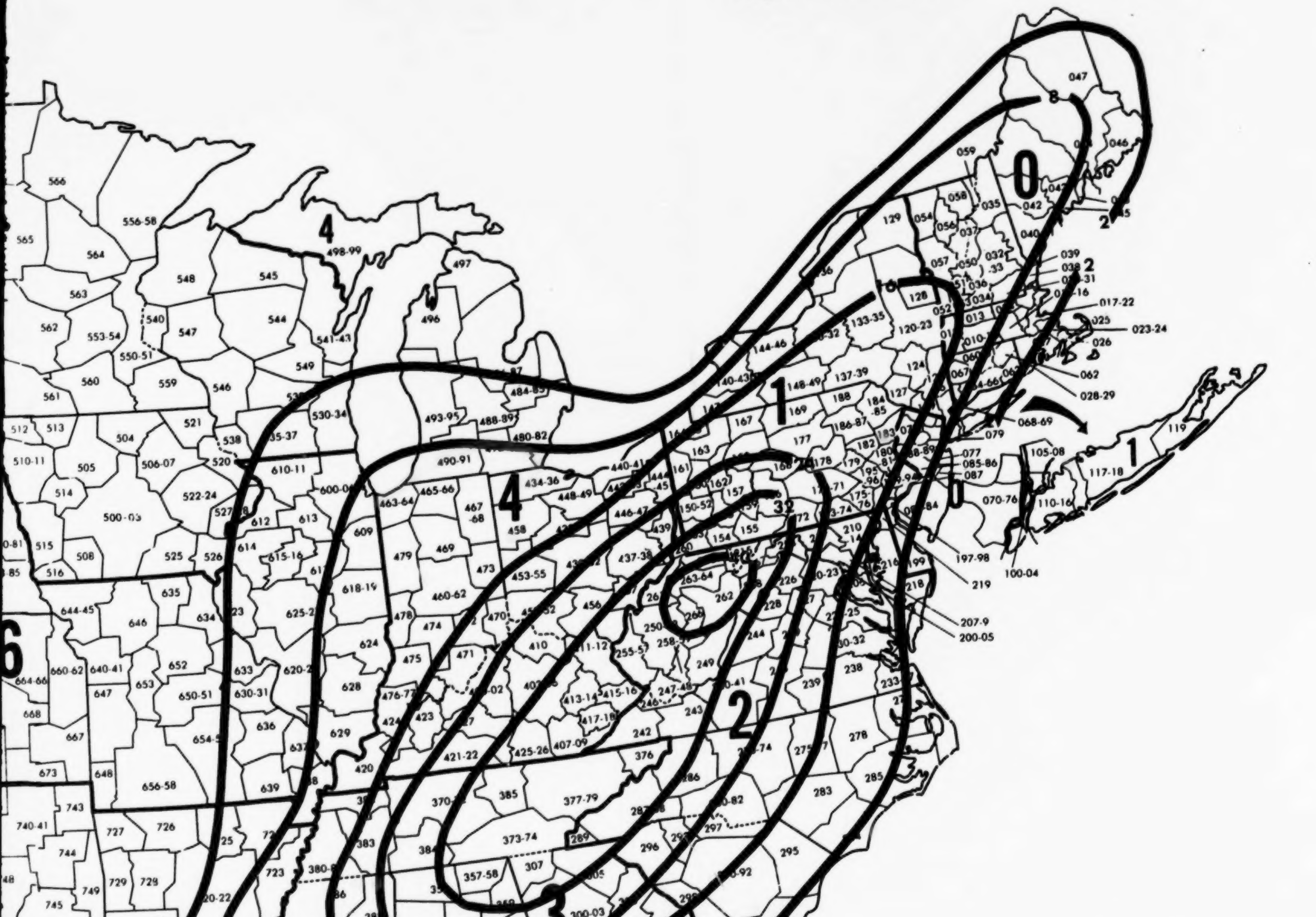
Figure 3

ON POTENTIAL WARNING PERIODS
OR YEARS INDICATED

Eastern United States:
Forty-one warnings issued from
August 1960 to June 1964



LEGEND

n — Total number of periods (n = 2, 4, 8, etc.) with predicted 36 hours or more continuous duration of simultaneous low-level inversion conditions and low mean wind velocities within the mixing depth

— State boundaries

— Sectional Center boundaries

— National Zip Code Area boundaries

Notes

1. "Zip Code Sectional Areas: Population and Sales Data," Commercial Atlas & Marketing Guide (100th ed.; Chicago: Rand McNally & Company, 1969).

2. *Ibid*., pp. 53-6.

3. *Ibid*., p. 56. Because a public opinion survey of households was to be conducted as a part of this study, a similar ranking of number of households was developed. The same metropolitan areas appeared in this ranking as in Table I; thus, to minimize any confusion in the use of population data, no further reference to number of households was considered.

4. *Ibid*., pp. 53 and 56.

5. Current Population Reports, Series P-25, No. 432, October 3, 1969.

6. The Post Office Department refers to a three-digit zip code area as a "Sectional Area." Mail is distributed throughout a Sectional Area from a town or city, referred to as a "Sectional Center," which is the principal transportation hub of the Sectional Area.

7. It was not in the scope of this study to determine whether the linear or linear-modified weighted values, as defined in Chapter III, best represent the odor producing potential of groupings of industrial plants in three-digit zip code areas. However, a review of a number of business and industrial journals provided some indication that the linear-modified values might be the best choice.

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CHAPTER VI

SURVEY OF LOCAL AIR POLLUTION CONTROL AGENCIES

This chapter is divided into two major sections. The first provides a summary of the development and results of the survey of local air pollution control agencies conducted by Copley International Corporation. The second provides a summary of the documentation of odor problems prepared by Engineering-Science, Inc., from discussions with representatives of air pollution control agencies in seven metropolitan areas.

Frequent references are made to Appendix D. It contains a summary of the survey results; a copy of the questionnaire, the cover letter, and the follow-up letter sent to each agency; and several examples of complaint forms used by state and local air quality control organizations.

DEVELOPMENT OF THE QUESTIONNAIRE AND RESULTS OF THE MAIL SURVEY

The primary objective of this survey was to identify areas in the United States where local air pollution control agencies believe that significant odor problems exist. A secondary objective was to gather professional opinion and information from local air pollution control agencies concerning:

- The extent and seriousness of existing odor problems.
- The means by which they define and assess these problems.
- Their opinions of public reaction to the problems.

Development of the Questionnaire

In view of the nature of the information desired and the scope of this investigation, a mail survey was considered the most feasible means of obtaining the data. Accordingly, a rough draft questionnaire was developed. This draft was critiqued by officials of the County of San Diego, California, Department of Public Health. Further refinement was attained through discussion and correspondence with the National Air Pollution Control Administration.

A final pretest was conducted by mailing a preliminary form to a sample of ten local air pollution control agencies scattered across the nation. The responses of these agencies were evaluated for clarity and completeness. As a result, a few minor revisions were made. The final form was then submitted to NAPCA and the Bureau of the Budget for approval. A copy of the approved questionnaire is included in Appendix D.

The questionnaire was designed to obtain a broad view of each local air pollution control agency. It covered the geographic and budgetary scope of the agency, the extent of odor problems in its district (nature of source, area and population affected, degree of seriousness, etc.), the identification and assessment of problems, the use of odor abatement measures, and the degree of recognition of odor problems by the local mass media.

Specifically, Questions 1 through 3 were designed to determine the geographic area and number of people in each local air pollution control district. Question 4 dealt with the local agency's total annual budget and that portion applied to odor problems.

Question 5 asked for a descriptive list of individual odor problems from the agency's complaint records. For each specific odor problem listed, information was requested on the source of the odor, the area affected, the number of people affected, the rate of complaints generated, the degree of seriousness of the problem, and its development over time.

Question 6 focused on the means by which the agency assessed odor problems. It asked how the public was contacted, what types of data were collected from the public, what tasks were performed by the technical staff in assessing odor problems, and what types of equipment were used. Question 7 asked for information on how each agency handled the abatement of odor problems.

Question 8 requested estimates of the number of news items on air pollution carried by the local mass media. And, Question 9 inquired whether or not any odor pollution studies had been conducted in the agency's district. The final question (No. 10) asked for any additional information that might assist in defining and assessing the nature and seriousness of odor problems in general.

Questionnaires were mailed to the chief officers of 184 local agencies selected from the Air Pollution Control Association 1969 Directory (of) Governmental Air Pollution Agencies. All questionnaires were mailed with a personally addressed and signed covering letter and a stamped, self-addressed envelope to facilitate the return.

Most of the questionnaires were mailed on September 3, 1969. A follow-up letter was mailed on September 30 to the agencies that had not responded by that date. Personal telephone calls were placed about mid-October to those who still had not responded. See Appendix D for copies of the covering and follow-up letters.

Of the 184 agencies to which questionnaires were mailed, 109 responded — a response rate of 59 percent. Of the 109 responses, nine were not usable, primarily because of a lack of sufficient information. Of the 75 making no response at all, the impression received from the telephone discussions was that they did not have the personnel available to complete the questionnaire within the established time limit.

The following analysis is thus based on the 100 usable questionnaires which were completed, wholly or in part, and returned. These responses represented almost 55 percent of the total sample.

Results of the Mail Survey

While there was no way of knowing whether the information received from the responding agencies is typical of all agencies, the distribution of the responding agencies by type and size of district and by geographic distribution suggested that a highly representative sampling of all agencies was obtained.

Responses indicated that some of the agencies have a legal jurisdiction confined to corporate city limits, some to single counties, and some to clusters of counties. However, the most common finding was that of an agency responsible for a single county, with well over half of the agencies falling into this category (Appendix D, Table 1. Note that the table numbers are comparable to the question numbers on the questionnaires).

The size of the air pollution control districts ranged from a relatively small 2.5 square miles up to a substantial 37,500 square miles (reported by the Anchorage, Alaska, agency). The average size of all reporting agencies was computed at about 1,935 square miles per district (Appendix D, Table 2).

The total population contained in the districts represented by the reporting agencies was approximately 51 million or about one-fourth of the population of the United States. The population of these districts ranged from a low of 30,000 to a maximum of 4,150,000 with an average population figure per district of approximately 510,000 (Appendix D, Table 3).

There was also a very wide range in the total annual budget reported by the agencies (Appendix D, Table 4A), with a reported low of $11,000 and a maximum of approximately $1,835,000. The annual budget most agencies reported was around $200,000. It is noted that while some agencies reported their budgets for air pollution control, as requested, an unknown number of others reported the total budget of the environmental and health organizations of which they are only a part. Due to the lack of consistency in reporting, the summaries of budget data must be viewed with reserve.

Reporting agencies estimated the proportion of their total annual agency budget applied to odor problems in the last fiscal year as exceedingly small. Almost half of the agencies stated they devoted less than one percent of their total annual agency budget to odor problems, while 70 percent spent less than 5 percent. Only four of the 100 responding agencies spent over 25 percent of their budget on odor problems. For all agencies, the average proportion of the total agency budget applied to odor problems in the last fiscal year was approximately 6 percent (Appendix D, Table 4B).

Over half of the reporting agencies (52) had a population density in their districts that could be considered as light — less than 1,000 persons per square mile. About a third of the agencies (31) had a moderate density, with from 1,001 to 5,000 persons per square mile, while 13 indicated a heavier density with more than 5,000 persons per square mile (Appendix D, Table 4C).

Almost three-fourths of the reporting agencies (72) had a per capita annual budget of less than $0.50 for air pollution control in their districts. Only seven agencies reported spending more than $1.00 per capita. The average expenditure for all reporting agencies was estimated at approximately $0.38 per person. That proportion of the budget devoted to odor problems was estimated at an average of only $0.02 per person.

Eighty-five of the agencies reported having one or more odor problems in their districts. The average number of complaints received by these agencies over the last 12 months was approximately 148, although the number of complaints ranged from two for one agency to 1,600 for another (Appendix D, Tables 5A and 5B).

However, odor complaints were a relatively small percentage of all air pollution complaints received by the agencies in the past 12 months. Only seven agencies reported that their proportion of odor complaints (as a percentage of all complaints) ran over 50 percent. The average proportion for all reporting agencies was approximately 24 percent (Appendix D, Table 5C).

Almost half (40) of the agencies experiencing odor problems in their districts indicated they had no criteria for defining the problems, while most of the other reporting agencies used criteria involving a greater or lesser degree of subjectivity. Only six agencies reported using scentometers or other scientific instruments in defining odor problems (Appendix D, Table 5D). These findings strongly support the reported need for improved air quality criteria relating to odors.

Agencies with odor problems were requested to:

- List each specific problem.
- Identify its source.
- Estimate the number of square miles affected.
- Estimate the number of people affected.
- Indicate the average number of complaints received each month.
- Indicate the degree of seriousness of each problem.
- Indicate each problem's progression over time.

The agencies responding to this question listed a total of 452 specific odor problems. The sources responsible for these problems were classified into 23 categories. Four of these categories accounted for almost half (48 percent) of the total number of sources. These four categories were: rendering/meat packing/slaughterhouses; chemical/plastic plants; sanitary land fill/dumps/open burning/

incinerators; petroleum and natural gas refining/asphalt production (Appendix D, Table 5E-1).

Considering the average number of square miles affected per odor source, motor vehicles were by far the worst offenders, followed by pump/kraft/wood mills. Next in rank were sanitary land fill/dumps/open burning/incinerators, followed by fruit and vegetable processing plants. Petroleum and natural gas refining/asphalt production were next, followed by animal farms/feed lots/stockyards (Appendix D, Table 5E-2).

A somewhat different ranking was obtained by considering the average population per odor source in the affected area. Motor vehicles were again ranked first, followed by the category which included sanitary land fill/dumps/open burning/incinerators. Next in line were pulp/kraft/wood mills; then steel mills/foundries/metal works, followed by fisheries and fish processing, and then chemical/plastic plants.

Another means of examining these data was to consider the monthly average number of complaints per odor source (Appendix D, Table 5E-3). The monthly average number of complaints per odor source for all sources listed was 4.9. Six of the odor source categories had higher averages as indicated in Table I.

As a part of this examination of odor sources, the agencies were asked to rate each source as to its degree of seriousness on a scale of: critical, very serious, serious, moderately serious, not serious. They were also asked to note if they felt each source was: more serious each year, continuously serious, occasionally serious, less serious each year, not serious.

Had the odor source categories contained enough individual sources in each category (at least 20 listed sources per category) to permit percentaging over the five-point scale, the information developed would have been more useful. As reported, only nine categories produced large enough samples to be meaningful. Table II presents a summarization of these nine categories.

The nine categories of Table II are listed by rank in terms of most serious to least serious. The column labeled "Situation Over Time" ranks each category in terms of its progressive seriousness (Rank 1 relates to the fastest growing problem). For example, pulp/kraft/wood mills are ranked third in terms of overall seriousness, but rank first in terms of becoming more serious each year.

Table I

ODOR SOURCES WITH ABOVE AVERAGE NUMBER OF COMPLAINTS PER MONTH

Source Category	Monthly Average Number of Complaints Per Odor Source
Sanitary land fill/dumps/open burning/incinerators	15.4
Fisheries and fish processing	9.0
Rubber/tires production	8.3
Coffee roasting/spices	5.6
Chemical/plastic plants	5.3
Pulp/kraft/wood mills	5.2

Source: Copley International Corporation

Table II

NINE CATEGORIES OF ODOR SOURCES RANKED BY DEGREE OF SERIOUSNESS AND SITUATION OVER TIME

Source Category	Rank By Degree of Seriousness	Rank By Situation Over Time
Chemical/plastic plants	1	6
Rendering/meat packing/slaughterhouses	2	5
Pulp/kraft/wood mills	3	1
Steel mills/foundries/metal works	4	8
Sewage/human wastes	5	2
Animal farms/feed lots/stockyards	6	4
Sanitary land fill/dumps/open burning/incinerators	7	3
Petroleum and natural gas refining/asphalt production	8	7
Commercial: restaurants/dry cleaning plants/etc.	9	9

Source: Copley International Corporation.

Another series of questions examined the use of agency staff in handling odor problems. About half of the reporting agencies indicated they established contact with the general public (home owners, residents, complainants, etc.) as odor problems were brought to their attention. However, almost a third of the agencies said they established contact with representatives of the offending sources, generally industrial and business management. Only three agencies said they made random samplings of the public in order to develop systematic data (Appendix D, Table 6A-1).

In contacting people concerning odor pollution problems, 35 of the agencies reported they generally talked to less than 25 individuals, while only six agencies reported generally talking to more than 100. The number of people contacted averaged about 59 for all agencies, with a wide range of from one to 750 (Appendix D, Table 6A-2).

Over half of the responses indicated that air pollution control agency personnel initiated contact with the general public. Half of the agencies also reported having formal procedures for collecting data, while the other half had very informal procedures (Appendix D, Tables 6A-3 and 6A-4).

Those agencies with a technical staff available to use in assessing odor problems indicated a wide range in the type of work performed by the staff. The most frequently mentioned activities were routine surveillance and investigation of complaints. A substantial number of agencies engaged in various forms of meetings with representatives of the offending sources wherein corrective recommendations could be made. A smaller number of agencies had their staffs engage in instrumented field investigations with greater or lesser degrees of sophistication (Appendix D, Table 6B).

In a question on the type(s) of test and/or measurement equipment used in assessing odor pollution problems, the scentometer was mentioned most often — by 12 agencies (Appendix D, Table 6C). About half of the agencies listed some type of test and/or measurement equipment, the other half stated they had no such equipment.

Question 6D was open-ended, asking for additional comments on the agencies' methodologies in identifying and assessing odor problems. Appendix D, Table 6D, presents the verbatim comments made by the responding agencies.

One observation to be readily made from studying these comments is that there are two distinct schools of thought, about equally divided in the number of adherents. One group feels the identification and measurement of odor problems is a relatively simple one, dependent upon the nose, common sense, and the number of complaints. The other group realizes that there are many inadequacies in the current methods used to assess odor pollution and express a need for assistance in this area.

The great majority of those agencies reporting odor problems takes some sort of abatement action (Appendix D, Table 7A). One of the most popular approaches to abatement appears to be that of "friendly persuasion." About a third of the agencies fall into this category, citing the use of conferences, meetings, requests for cooperation, and other forms of persuasion.

Another third of the agencies takes a harder line on abatement. This group reports having established requirements for abatement equipment, including afterburners, filters, scrubbers, incinerators, aerators, and condensors. Others require a change in operating time or changes in production procedures.

Only a fifth of the agencies takes an enforcement approach to abatement, resorting to ordinances, regulations, legal actions, and prosecution. In contrast, a few agencies reported that they investigate and evaluate odor problems but take no follow-up action.

The means currently available to agencies to enforce abatement of odor pollution problems are few in number, but are used to some extent. The most frequently mentioned was the use of air pollution regulations and ordinances, followed by the use of local nuisance regulations. A few agencies mentioned recourse to sanitation and health ordinances. Well over a fourth of the agencies appeared to have no means of enforcement available (Appendix D, Table 7B).

A series of questions was asked to determine the amounts of attention air and odor pollution have received in the local mass media (Appendix D, Tables 8A, 8B, 8C and 8D). Responding agencies estimated an average of eight stories per month were run in the major local newspapers in their districts. They also estimated that approximately seven stories were aired each month by the local radio and television stations in their districts. While the local print and broadcast media tend to give equal treatment to air pollution problems on the average, there is a fairly wide range of attention when individual districts are considered.

Responding agencies also estimated that on the average approximately 13 percent of the air pollution stories in print dealt in whole or in part with odor problems. The comparable figure for radio and television was 8 percent. Again, there was a very wide range between individual districts.

Putting these averages into a time frame, it can be said that newspapers in the average district run about one story per month on odor problems, while radio and television carry about one story every two months.

The majority of responding agencies indicates that no odor studies have been conducted in their districts (Appendix D, Table 9). Of the few agencies which indicated studies had been done, only seven had formal, printed study reports which they were able to enclose with their questionnaires.

The last question was open ended, asking for additional comment and information (not already covered in the questionnaire) which agency personnel felt NAPCA should be aware of in relation to defining and assessing the nature and seriousness of odor pollution problems. Appendix D, Table 10, contains the verbatim comments of those who responded.

The contents of most of these verbatim comments can be easily summarized into one or more of the following categories:

- More work and attention needs to be given to odor measurement and testing.
- No local air and/or odor pollution laws are available to use in abatement.
- Most odors are of a temporary and minor nature, are under control, and warrant little attention.
- More basic study of odors is needed, such as their complex chemical makeup, their affect on people, etc.
- Abatement of odors is best accomplished by utilizing nuisance ordinances.
- Most odors arise outside the district boundaries and are beyond control.

SUMMARY OF DOCUMENTATION OF ODOR PROBLEMS

With the assistance of the National Air Pollution Control Administration, arrangements were made for a team of engineers from Engineering-Science, Inc., to meet with air quality control agency representatives in each of the seven metropolitan areas selected for the investigation of actual odor problems.

The procedural format of these meetings required a two-day visit to each area and accomplishment of the following:

- Introductory meeting with the local administrators.
- Orientation by field investigators to establish a common context to facilitate discussion of the situations where odors were found in that area.
- A technical level meeting to develop descriptions of the technical information available in each agency for documenting odor situations.

- A one-day field investigation of industrial and other sources of odorants in each area, at which time additional informal interviews were conducted with available agency representatives.

The orientation sessions with the local administrators were conducted at a level of informality designed to circumvent the formalized responses and elicit expressions of the informal feelings. Structure was limited to the consideration of certain empirically selected issues deemed basic to the operation of an air pollution control agency.

Each of the two-day studies served to develop a reservoir of both technical and non-technical information. The technical information is discussed in detail in Chapter VIII. The non-technical observations of the ESI team, relating to the documentation of odor problems, are presented in the balance of this chapter. This information was generated within the context of the major functional areas of activity of the air pollution control agencies visited: receipts of complaints and investigations, abatement activities, technical studies, and public relations.

Complaints and Investigations

All of the agencies visited maintained records of citizen odor complaints on some type of standardized form. The vast majority of all complaints are received by telephone and handled by inspectors or clerical personnel. Information requested by agencies receiving odor complaints typically includes: name and address of complainant, nature and strength of the odor, time and duration of the odor, suspected source (often obvious in chronic problem areas), and, occasionally, wind direction. Typical complaint forms are presented in Appendix D.

Complaint records are filed by a variety of systems, which are summarized in Table III.

Table III

FILING SYSTEMS FOR AIR POLLUTION COMPLAINTS

System*	Number of Agencies Using**
By source category (industrial, commercial, etc.)	1
By violation category (particulates, odors, etc.)	4
By geographical area	2
By name of violator	6

* Systems above refer to primary categorization schemes; within each category other systems may prevail.

** Some agencies retain multiple copies and file according to differing methods. These agencies are counted more than once in the above table.

Source: Engineering-Science, Inc.

None of the air pollution control agencies visited maintained separate odor complaint files. Those agencies which categorized air pollution complaints according to type included odors with other types of complaints such as "irritation" or open burning. Moreover, many air pollution complaints involving odors are filed according to associated phenomena, such as visible emissions.

Investigations of odor problems by air pollution inspectors are initiated on the basis of citizen complaints, routine air pollution patrols, and site visits to known odor sources to verify compliance with odor abatement arrangements. The alacrity with which investigations of odor problems are initiated depends upon the nature and intensity of the odor reported, the size of the area affected, the size of the agency involved, and the time of day in which the odor was first reported.

Certain odors, such as those associated with natural gas leaks, receive immediate response in all agencies. Most large agencies attempt to dispatch an inspector to the site immediately upon receipt of an odor complaint, primarily in order to allow personal assessment of the odor by the inspector. Radio contact with inspectors in the field, provided in about half the agencies visited, greatly increases the ease with which this can be accomplished. Smaller agencies with limited staffs investigate odor complaints according to a routine schedule of visits to various geographical sectors of the area under the jurisdiction of the agency.

An odor investigation by an inspector usually begins with a visit to the affected area in an attempt to personally assess the odor. Personal contacts with the complainant may follow, especially if no odor is perceived by the inspector. Interviews by air pollution inspectors of odor complainants require considerable skill in order to obtain relevant information. Inspectors noted the following problems: (a) "cranks" or citizens registering persistent complaints of odors not perceptible to neighbors; (b) descriptions of odors in terms meaningless to anyone but the complainant; and (c) attribution of odors to sources guilty of problem odor emissions in the past, whether odors were of similar quality or not.

The specific information developed by inspectors in the course of odor investigations is virtually identical to that cited above for citizen complaints. In most agencies an inspector's report is either included on the same form used for a citizen complaint (Appendix D, Pages D-36 and D-37), or is recorded on another copy of the same form. The State of New Jersey is unique in that a special form is used for odor investigations (Appendix D, Page D-34). In no agency visited did inspectors routinely record odor intensities in terms other than verbal, although scentometers were on hand in two agencies.

In general, records of odor investigations are filed either with complaints, as described previously, or by the name of the odor source in files maintained in conjunction with abatement proceedings, as described below.

Abatement Activities

A detailed consideration of the administrative and legal methodology by which the air pollution agencies effected odor abatement is outside the scope of this study. However, a few observations relative to the documentation of odor problems are provided below.

The first step in the abatement process of odor problems is the identification of the source. In most odor situations this is readily accomplished by experienced enforcement personnel. Source identification is usually followed immediately by direct contact with the source. The air pollution inspectors interviewed in the course of the study often knew plant operating staffs personally for those industries with a history of odor problems and, in many cases, were able to identify the specific reason for the odor emission (certain product runs, chronic process upsets, etc.) even before contacting the sources.

The documents generated within the context of abatement activities fall into four categories: correspondence between the agency and the violator, records of hearings, compliance agreements, and reports of inspectors verifying compliance. In the agencies visited, these documents were available in a separate file maintained for the violator involved. The following types of information were found in the abatement files inspected in the field technical program:

(1) Information on the intensity and areal extent of odor episodes, as contained in complaint investigation reports prepared by inspectors.

(2) Technical data relative to operating conditions causing odors and to process modifications or equipment specified for odor abatement.

(3) Records of procurement, delivery, and installation of process modification or specialized pollution abatement equipment obtained in compliance with abatement orders, together with reports of inspectors on the efficacy of such arrangements.

Technical Studies

Technical studies may be grouped into the following broad categories: ambient air quality characterization, air pollution source inventories, meteorological studies, and special studies relating to specific types of industries or pollutants. In general, the agencies visited accorded technical study priorities in the order of these categories. Of the eleven agencies visited, all conducted ambient air testing (although the number of analyses varied) and three conducted source testing. About half the agencies had accomplished or participated in meteorological studies related to air pollution.

In the context of odor problems, ambient air quality, air quality characterization, and source testing are of little value except for data compiled relative to hydrogen sulfide or sulfur dioxide. Meteorological studies, on the other hand, proved very useful in understanding the nature of odor problems because of the direct relationships observed between odor levels in a given area and wind direction and/or atmospheric mixing conditions.

Special studies relating to the general problem of odors had been conducted in three of the seven metropolitan areas visited. All of the studies consisted of surveys of odor violations by geographical area, together with data regarding the nature and source of the odor. Other factors considered included meteorology and measurement methodology.

Access to Odor Documentation

The air pollution agencies interviewed in the context of this study indicated similar policies and attitudes toward public access by agency documents. Citizen complaints, investigations, records of informal hearings, and source testing data are almost universally regarded as privileged information, either to protect private citizens from possible retaliation by neighbors or employers, or to protect industrial secrets. In general, any information gained by inspectors via privileged access to sources of air pollution was regarded as privileged information.

In all agencies interviewed, ambient air quality data, meteorological studies, and public relations publications were open to the public. Official policies toward access to records of abatement actions varied, but in practice all of the agencies were reluctant to make such information available to the public, usually citing a policy of "trying to work with industry without making headlines."

In all but two of the agencies visited, the team of engineers from ESI was given full access to all records based on the NAPCA support of the project and contingent upon assurances that no data regarded as privileged would be divulged in the study report or by any other means. Of the two agencies imposing restrictions, only one specifically denied access to documents desired by the study staff.

Public Relations

All eleven of the agencies interviewed conducted public relations programs. The objectives of public relations efforts were cited as development of public awareness with regard to air pollution and informing the public of progress being made by the agency. Public relations efforts were carried out principally by means of public speaking engagements before various civic groups, and the distribution of publications prepared either by NAPCA or the local agency.

All of the publications prepared by the agencies interviewed paid scant attention to odors, despite the tendency of odor problems to generate intense citizen concern. This was apparently due to the tenuous position of the agencies regarding odor measurement and abatement.

CHAPTER VII

THE SELECTION OF SEVEN METROPOLITAN AREAS FOR INVESTIGATION OF ACTUAL ODOR PROBLEMS

One of the primary objectives of this study was to develop a means of identifying potential odor problem areas throughout the United States. This was accomplished as reported in Chapters II through V. The most likely odor problem areas were found to be metropolitan areas with a broad representation of industries known to be potential sources of odorant emissions. A second objective was to investigate the extent of actual odor problems in seven of these areas selected from different parts of the nation. The results of the investigations were to be projected to the nation as a whole. The criteria used in the selection process are outlined in this chapter.

Initial Selection of Thirty-One Metropolitan Areas

The initial task in the selection process was to develop a list of potential odor problem areas from which the seven metropolitan areas could be selected. Only those areas included in each of the following rankings were given further consideration:

(1) The fifty metropolitan areas having the largest number of persons (Chapter V, Table I).

(2) The principal counties of fifty Standard Metropolitan Statistical Areas having the highest densities of population (Chapter V, Table II).

(3) The fifty metropolitan areas having the highest linear weighted values of industrial plants (Chapter III, Table IV).

(4) The fifty metropolitan areas having the highest linear-modified weighted values of industrial plants (Chapter III, Table V).

The assumptions which formed the basis of this initial task were:

(1) That odor problems would be more extensive in areas supporting large and compact, rather than smaller or less dense, populations.

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(2) That the linear and the linear-modified weighting functions represent relationships between the level of odorant emission and plant output, but that insufficient evidence exists to permit a best choice. (It was not within the scope of this study to obtain such evidence.)

(3) That the areas included on the list would provide adequate geographic representation to permit a selection of seven metropolitan areas from different parts of the nation.

(4) That each of the areas listed would contain a large number of industrial plants representing many of the SIC classifications discussed in Chapter III, and that, consequently, a variety of odor problems would be encountered.

Thus, the initial screening of metropolitan areas eliminated those ranking in the top fifty in terms of population size but with relatively low population density. Others were eliminated because they did not appear in both odor producing potential rankings. In this manner, a preliminary list of thirty-one potential odor problem areas was developed. It is presented in Table I.

Table I

PRELIMINARY LIST OF THIRTY-ONE POTENTIAL ODOR PROBLEM AREAS

Metropolitan Area	Size of Population Rank	Linear-Modified Weighted Rank
New York, NY	1	5
Los Angeles, CA	2	4
Chicago, IL	3	2
Philadelphia, PA - Camden, NJ	4	7
Detroit, MI	5	10
Newark, NJ	6	1
San Francisco-Oakland, CA	7	9
Boston, MA	8	14
St. Louis, MO - East St. Louis, IL	9	8
Cleveland, OH	10	6
Houston, TX	11	11
Minneapolis-St. Paul, MN	12	15
Milwaukee, WI	13	13
Pittsburgh, PA	14	3
Baltimore, MD	15	12
Atlanta, GA	16	19
Kansas City, KS - Kansas City, MO	18	20
Dallas, TX	19	25
Buffalo, NY	20	21
Cincinnati, OH	21	17
Providence, RI	23	37
Indianapolis, IN	25	28
Columbus, OH	26	26
Tampa, FL	28	39
New Orleans, LA	30	48
Dayton, OH	34	31
New Haven, CT	35	23
Norfolk, VA	38	44
San Jose, CA	39	34
Portland, OR	40	36
Louisville, KY	48	16

Source: Copley International Corporation.

Final Selection of Seven Metropolitan Areas

Two additional criteria were used in the final selection of the seven metropolitan areas: geographic representation and the availability of local air pollution control agency odor complaint records.

Geographic representation was required to project the results of the investigations of actual odor problems in the seven metropolitan areas to an assessment of odor problems in the nation as a whole. To assure this, the thirty-one metropolitan areas were categorized by Census Region as indicated in Table II. Two metropolitan areas were to be selected from each of three regions and one area from the remaining region.

It was planned to locate actual odor problems in each of the areas finally selected with the assistance of representatives of the local air quality control agencies in those areas. Therefore, it was necessary to screen the thirty-one areas further to determine the degree of interest in the study on the part of agency administrators and the availability of odor complaint records.

Odor studies of a more specialized nature were previously conducted in three of the thirty-one areas of Table I. Telephone discussions with the agency directors in those areas confirmed their interest in odor problem research and the availability of odor problem data. Early results of the survey of local air pollution control agencies (discussed in Chapter VI), followed by additional telephone contacts, indicated interest and the existence of information in four other areas.

Table II

PRELIMINARY LIST OF THIRTY-ONE POTENTIAL ODOR PROBLEM AREAS BY CENSUS REGION

Northeast

Boston, MA
Buffalo, NY
Newark, NJ
New Haven, CT
New York, NY
Philadelphia, PA - Camden, NJ
Pittsburgh, PA
Providence, RI

North Central

Chicago, IL
Cincinnati, OH
Cleveland, OH
Columbus, OH
Dayton, OH
Detroit, MI
Indianapolis, IN
Kansas City, KS - Kansas City, MO
Milwaukee, WI
Minneapolis-St. Paul, MN
St. Louis, MO - East St. Louis, IL

South

Atlanta, GA
Baltimore, MD
Dallas, TX
Houston, TX
Louisville, KY
New Orleans, LA
Norfolk, VA
Tampa, FL

West

Los Angeles, CA
Portland, OR
San Francisco-Oakland, CA
San Jose, CA

Source: Copley International Corporation.

Based on the results of the selection process and the approval of the National Air Pollution Control Administration, actual odor problems in the following metropolitan areas were investigated:

- Portland, OR
- Kansas City, KS - Kansas City, MO
- Cincinnati, OH
- Buffalo, NY
- Philadelphia, PA - Camden, NJ
- Tampa, FL
- San Francisco, CA

Characteristics of the Seven Metropolitan Areas

Figures 1, 2, 3 and 4 indicate the positions of the seven metropolitan areas (by the arrows) in the distributions of the fifty areas having the largest number of persons, highest densities of population, highest linear weighted values, and highest linear-modified weighted values. As indicated, the seven areas provide a good representation of each of the distributions.

Figure 5 shows the locations of the seven metropolitan areas on a Census Region map of the United States. Geographic representation was achieved by selecting two areas in the Northeast, North Central, and West regions and one area from the South region.

Table III indicates the number of SIC classifications discussed in Chapter III that are represented in each of the seven areas. The number of industrial plants with a primary line of business corresponding to these SIC classifications is also indicated.

Meteorological information was not used in the selection of the seven metropolitan areas because of the expected short duration of the investigations in each area (one to three days for the technical field studies and five to eight days for the public opinion surveys). It was felt that investigations of longer duration or greater frequency would be required to relate atmospheric influences to the results obtained. However, for completeness, meteorological information was gathered for the days of the investigations (see Appendix E). Figures 6 and 7 show the locations of the seven areas in terms of the graphical summary presented in Chapter IV, Figure 20, and the atmospheric areas of the United States as identified in the Air Quality Act of 1967.

The investigations of actual odor problems in seven metropolitan areas were of two types — technical field studies and public opinion surveys. Chapter VIII deals with the technical field program conducted by a team of engineers from Engineering-Science, Inc. Chapter IX discusses the public opinion surveys of residents and businessmen directed by Copley International Corporation.

Because the investigations took place almost entirely in the principal cities of the seven metropolitan areas, the next two chapters include many references to the cities rather than the metropolitan areas themselves. Appendix E provides data on the locations of the most serious sources of odors, the neighborhoods affected, and the public opinion survey test and control areas in each of the cities investigated.

Figure 1

FIFTY METROPOLITAN AREAS IN THE UNITED STATES HAVING THE LARGEST NUMBER OF PERSONS

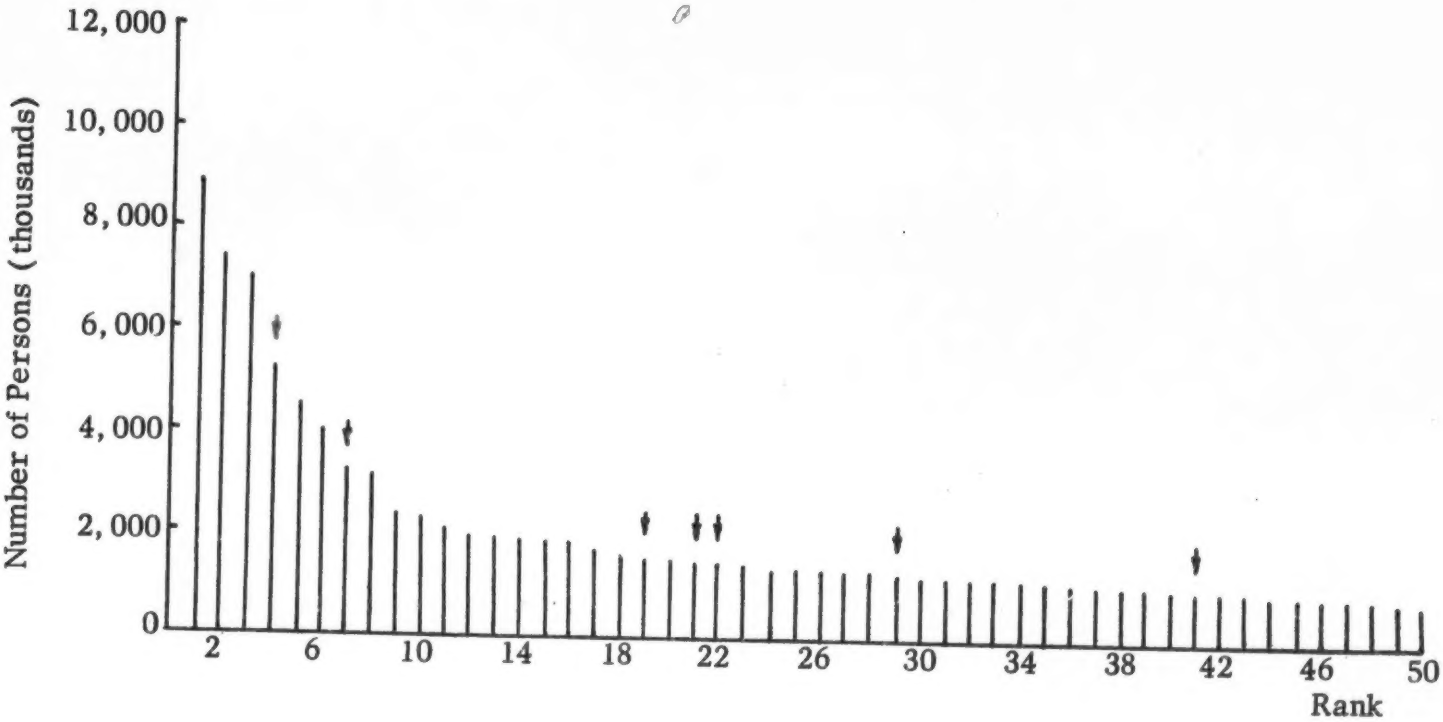
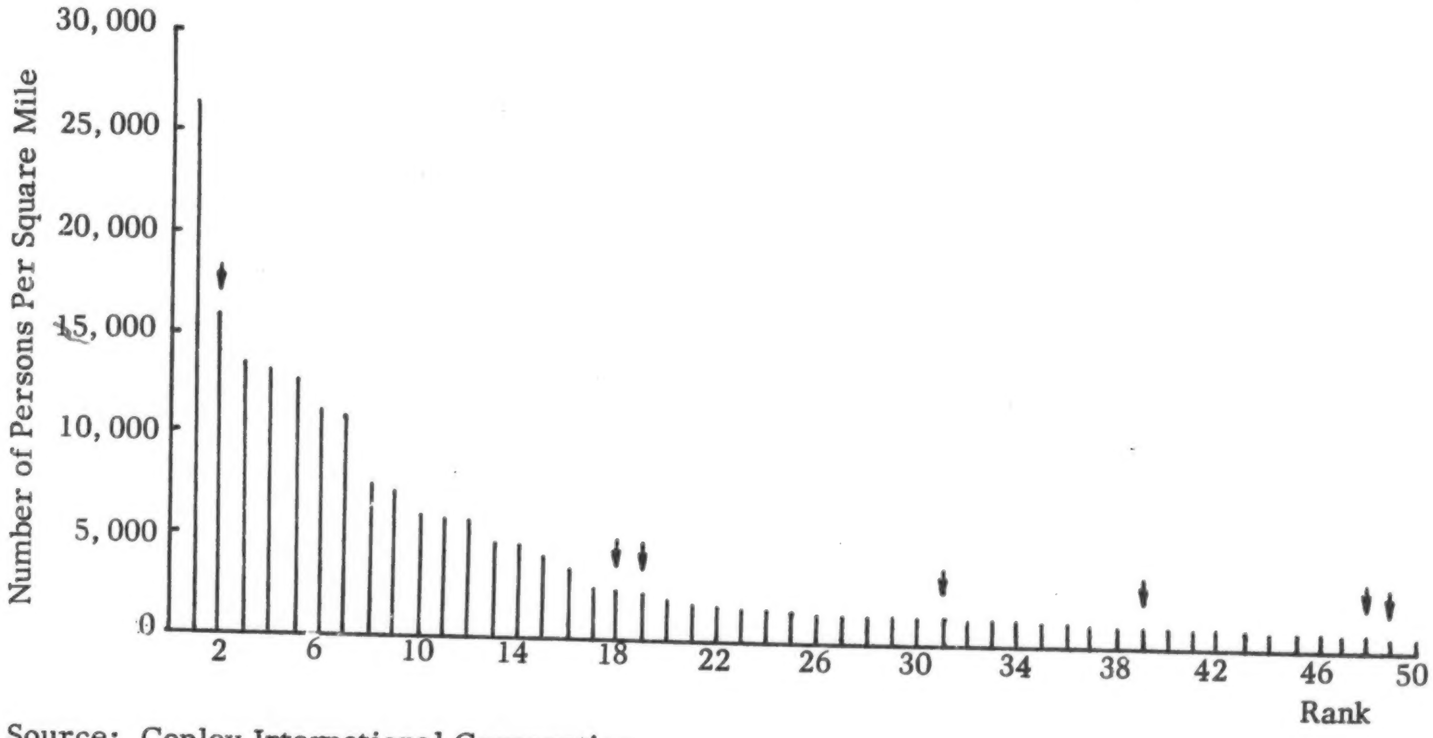


Figure 2

PRINCIPAL COUNTIES OF FIFTY STANDARD METROPOLITAN STATISTICAL AREAS IN THE UNITED STATES HAVING THE HIGHEST DENSITIES OF POPULATION



Source: Copley International Corporation.

Figure 3

FIFTY METROPOLITAN AREAS IN THE UNITED STATES HAVING THE HIGHEST LINEAR WEIGHTED VALUES OF INDUSTRIAL PLANTS

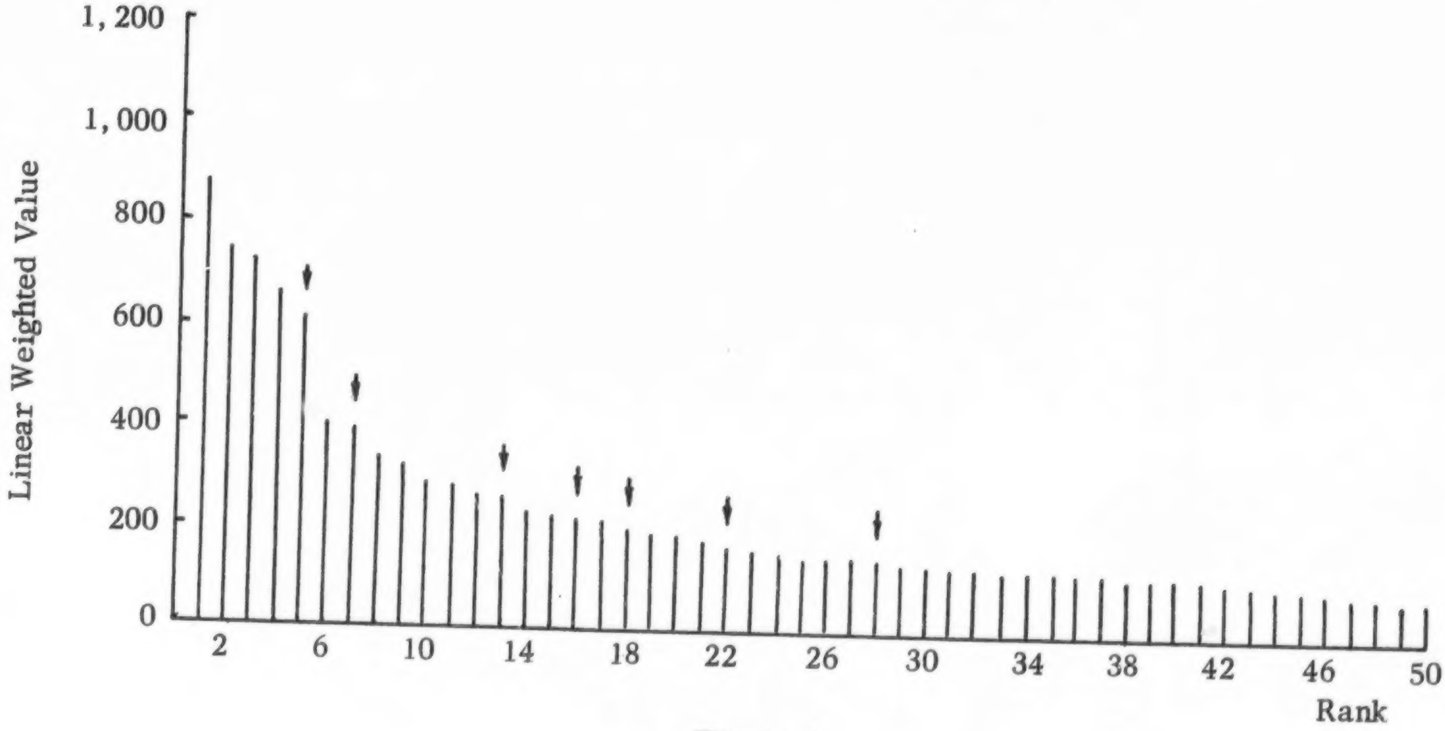
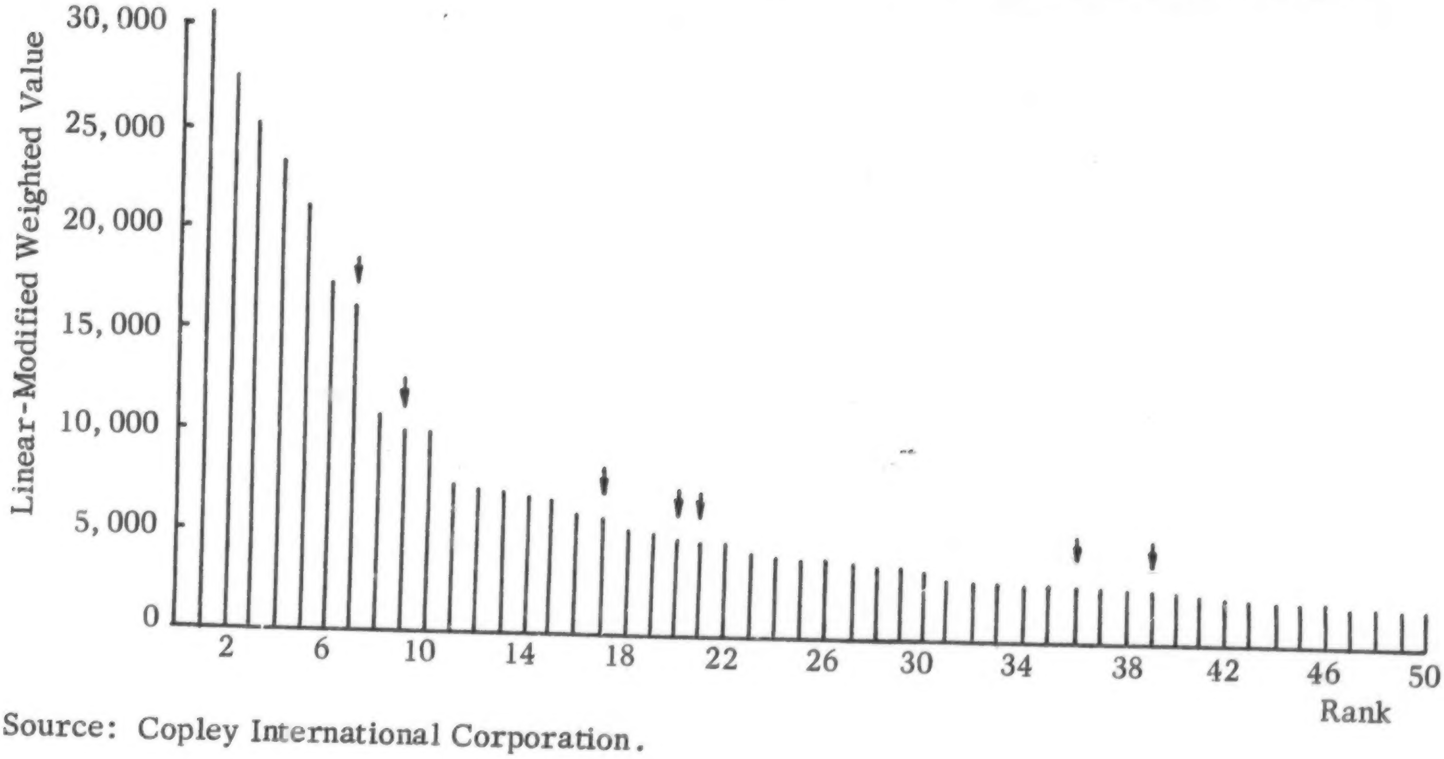


Figure 4

FIFTY METROPOLITAN AREAS IN THE UNITED STATES HAVING THE HIGHEST LINEAR-MODIFIED WEIGHTED VALUES OF INDUSTRIAL PLANTS

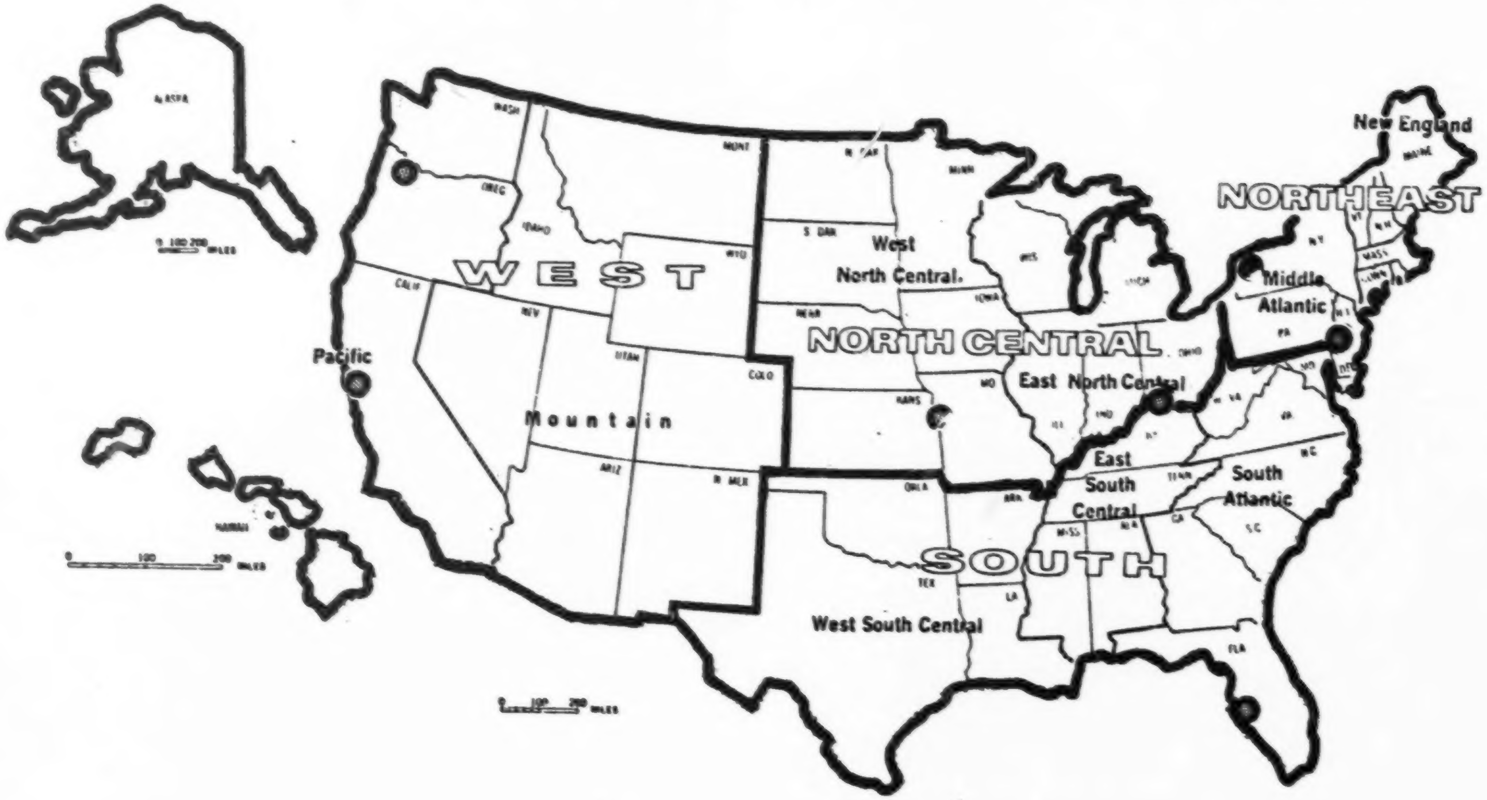


Source: Copley International Corporation.

Figure 5

MAP OF THE UNITED STATES, SHOWING CENSUS REGIONS AND DIVISIONS

[Alaska and Hawaii are drawn at different scales from conterminous United States and are not shown in their correct relative geographic positions]


WEST
Pacific
Mountain
NORTH CENTRAL
West North Central.
East North Central
SOUTH
West South Central
East South Central
South Atlantic
NORTHEAST
New England
Middle Atlantic
ALASKA
HAWAII
WASH
OREG
CALIF
IDAHO
NEV
MONT
WYO
UTAH
COLO
ARIZ
N MEX
N DAK
S DAK
NEBR
KANS
MINN
IOWA
MO
WIS
ILL
IND
MICH
OHIO
OKLA
TEX
ARK
LA
KY
TENN
MISS
ALA
GA
FLA
S C
N C
VA
W VA
MD
PA
N Y
N J
VT
N H
MAINE
MASS
CONN
0 100 200 MILES

Source: U.S. Bureau of the Census, Statistical Abstract of The United States: 1969.

Table III

NUMBER OF SIC CLASSIFICATIONS AND INDUSTRIAL PLANTS IN EACH OF THE SEVEN METROPOLITAN AREAS SELECTED FOR INVESTIGATIONS OF ACTUAL ODOR PROBLEMS

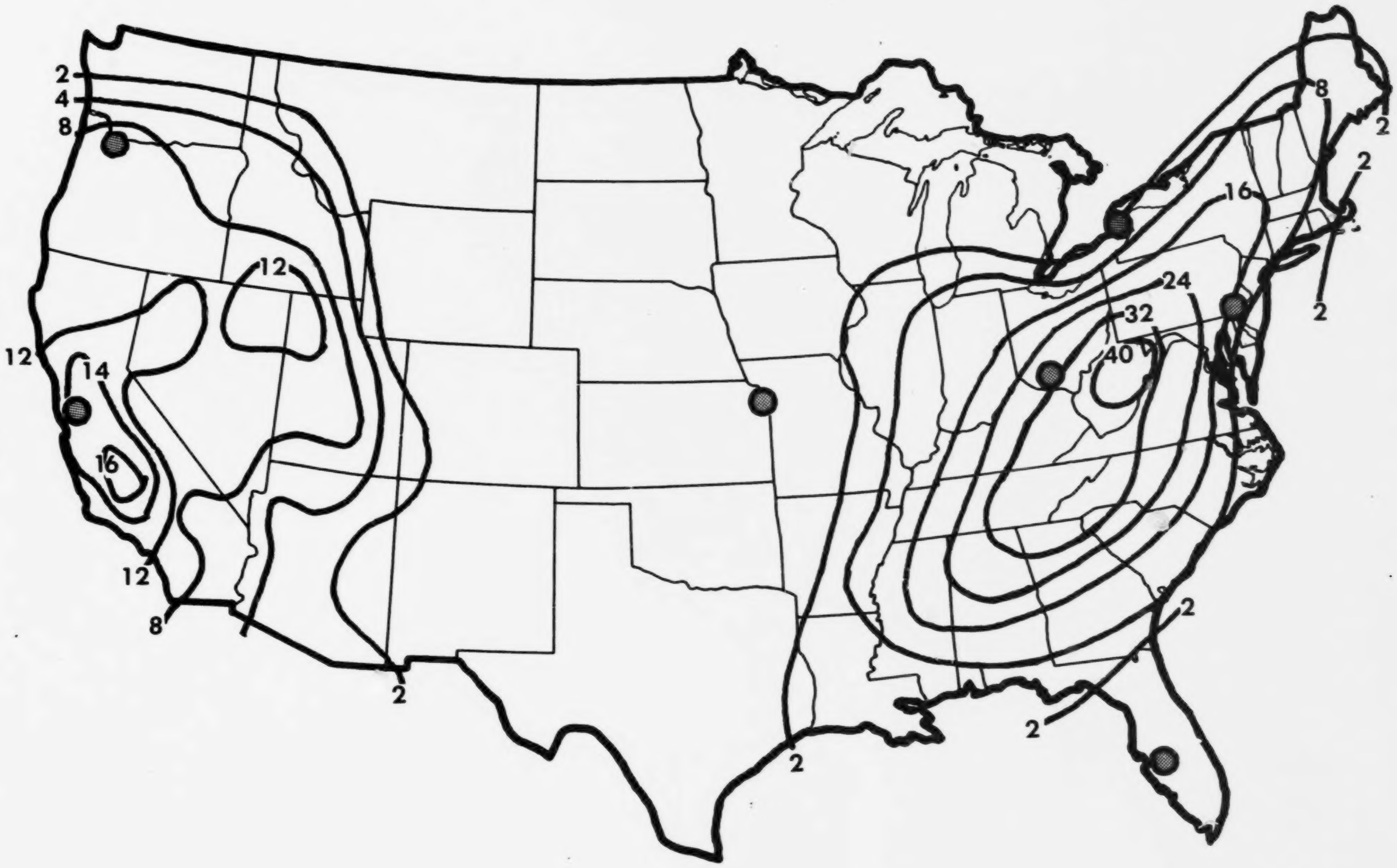
Metropolitan Area	No. of SIC Classifications*	No. of Industrial Plants*
Philadelphia, PA - Camden, NJ	43	819
San Francisco-Oakland, CA	42	543
Portland, OR	37	243
Cincinnati, OH	34	233
Buffalo, NY	34	218
Kansas City, KS - Kansas City, MO	32	184
Tampa, FL	30	152

* From Chapter III, Table I.

Source: Copley International Corporation.

Figure 6

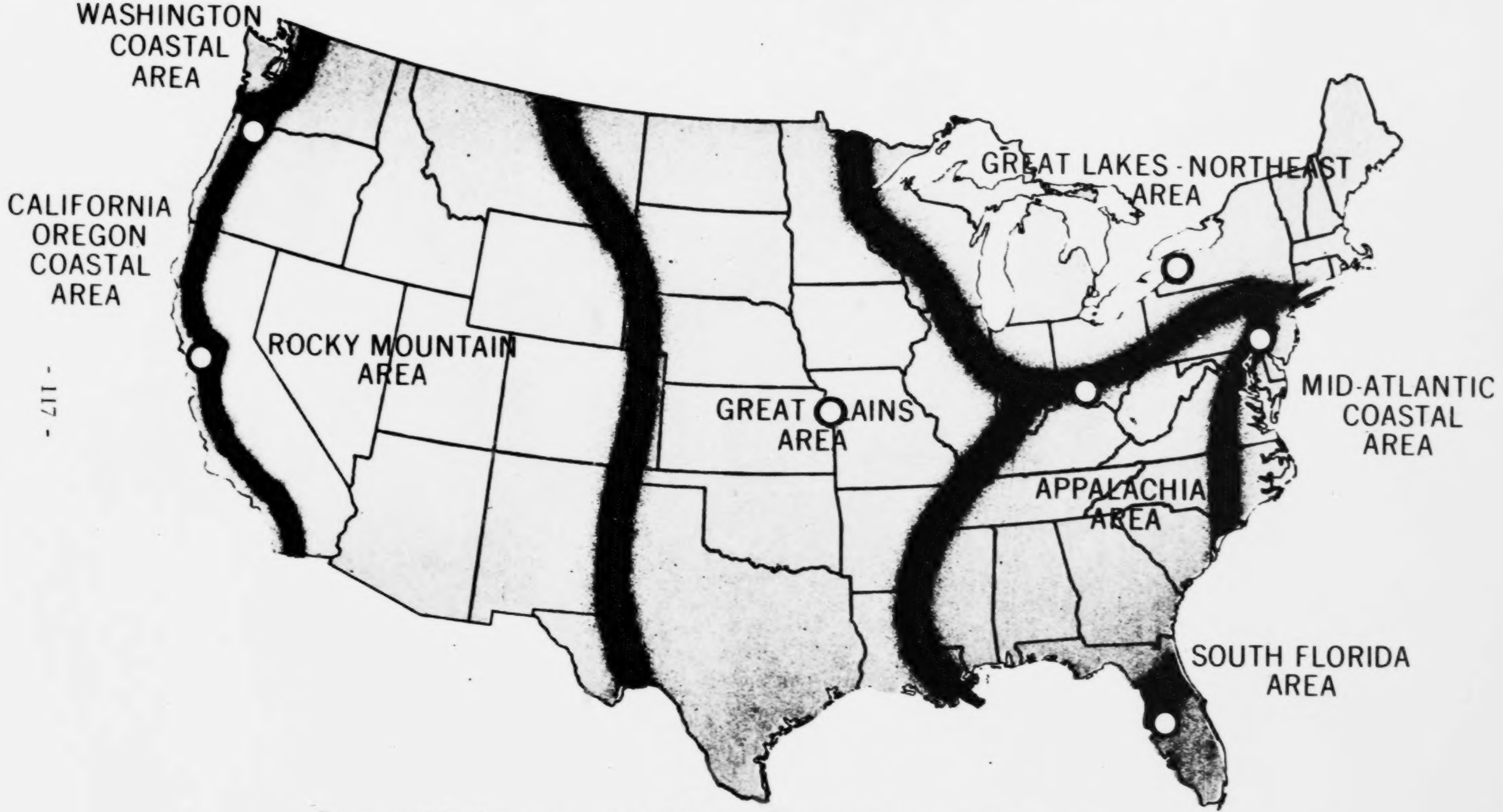
AIR POLLUTION POTENTIAL WARNING PERIODS
(Refer to Chapter IV, Figure 20)


2
4
8
12
14
16
12
12
8
2
2
2
2
2
16
24
32
40
8
2
2
2

Source: George C. Holzworth, "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XCII (May, 1964).

Figure 7

ATMOSPHERIC AREAS OF THE UNITED STATES


WASHINGTON COASTAL AREA
CALIFORNIA OREGON COASTAL AREA
ROCKY MOUNTAIN AREA
GREAT PLAINS AREA
GREAT LAKES - NORTHEAST AREA
MID-ATLANTIC COASTAL AREA
APPALACHIA AREA
SOUTH FLORIDA AREA

Source: U.S. Congress, Air Quality Act of 1967, Public Law 90-148, 90th Congress, S780, 1967.

References

Holzworth, George C. "Estimates of Mean Mixing Depths in the Contiguous United States," Monthly Weather Review, XCII (May, 1964), 235-242.

U.S. Bureau of the Census. Statistical Abstract of the United States: 1969.

U.S. Congress. Air Quality Act of 1967. Public Law 90-148, 90th Congress, S 780, 1967.

CHAPTER VIII

TECHNICAL FIELD PROGRAM

This chapter describes the development, activities, and results of the technical field program conducted by an Engineering-Science, Inc., team of engineers in the principal cities of seven metropolitan areas across the United States. The chapter is divided into three sections. The first section presents a detailed discussion of the odor analysis techniques used in the field activities. Sections two and three deal with, respectively, the two-day technical field investigations in each of the cities and the sensory evaluation of odor studies performed in Philadelphia, Pennsylvania.

The objectives of the two-day investigations were to:

(1) Develop, at the administrative level, a context for evaluation of technical information available in the agency relative to odor problem situations. (The results of this effort are presented in Chapter VI along with the results of the survey of local air pollution control agencies, conducted by Copley International Corporation.)

(2) Review, at the technical level, the technical documentation of odor problems available in the agency relative to specific odor problem observations as well as to meteorological and other conditions conducive to odor problems. (Documentation of odor problem areas in each of the seven metropolitan areas and meteorological conditions at the time of the field investigations are included in Appendix E.)

(3) Identify, through evaluation of information obtained in meeting objectives (1) and (2) and by direct field investigations, areas where odor problems exist, the extent of the areas affected, and the types of emission causing the concern. (Surveys of public opinion on the extent of odor problems were conducted in at least one of these areas in each of the cities investigated. These surveys are discussed in Chapters IX and X.)

Midway in the development of the technical field program, it became apparent that there was a lack of information demonstrating the utility of sensory evaluation techniques for documenting the time and intensity of odorant emissions. Under authorization by the National Air Pollution Control Administration, the technical program in the Philadelphia area was extended to include a study of the efficacy of sensory evaluation using odor quality reference standards. The objectives of this study were to:

(1) Apply direct sensory evaluation techniques to document odorant emissions from two sources, a rendering plant and a refinery, located in Philadelphia, and identified during the two-day study.

(2) Compare the responsiveness of the scentometer with the sensory evaluation technique.

(3) Develop and utilize a capability for sensory evaluation techniques as will be necessary for subsequent studies.

ANALYTICAL TECHNIQUES FOR ODOR EVALUATION

Three generic categories of odor analysis techniques are in use: sensory, chemical, and instrumental techniques. Sensory techniques are subjective methods relying completely on the human olfactory capacity. These methods are of primary interest to this study and are examined in detail in the following pages. Chemical and instrumental techniques are multitudinous in number and highly specific for individual classes or species of odorants within a defined range of odorant concentrations. The limitations in the utility of the latter methods are that odorified atmospheres are usually complex mixtures and that ambient concentration ranges often are very low. In contrast, the human nose is extremely sensitive to literally thousands of different odor qualities over a very broad range of concentrations. Sensitive noses are capable of detecting odors in quantities impossible to discern and track with commercially available instrumentation or chemical methods. Because of these reasons, as well as budgetary constraints, all consideration of analytical methods for use in the technical field program was directed to an evaluation of sensory methods.

Sensory Techniques

Sensory techniques can be classified broadly as field-oriented or as laboratory-oriented and in terms of whether or not a sampling step is required before the analysis is done. Field sensory techniques can be utilized either directly (obviating the need for sampling) or in conjunction with an intermediate sampling step. Direct field sensory measurements are used commonly in evaluating ambient odor situations. However, direct field sensory measurements are frequently impossible because of extremes of temperature or if concentrations of noxious components make the source intolerable for human exposure. Under such circumstances a sampling step is required. It is generally implicit that a sampling step is required in conjunction with laboratory sensory techniques.

The requirement of an intermediate sampling step is a major concern in the accurate determination of odorant levels. Sampling is required when the odorant must be diluted, concentrated, warmed, cooled, or otherwise modified, when a large uniform sample is required, or when transportation to analytical facilities is required. Amos Turk[1] has pointed out some of the problems associated with sampling:

(1) If the odorified sample is warm, then condensation on cooling may result in the selective removal of odorant from the vapor phase.

(2) Between the time of sampling and evaluation, odorous material may be sorbed on the walls of the container or on particulate matter in the sample.

(3) Chemical changes after sampling may alter the odorant.

These problem areas point out a key disadvantage of sampling and indicate the need for detailed evaluation of all sampling efforts to avoid alteration of the odor characteristics of the sample.

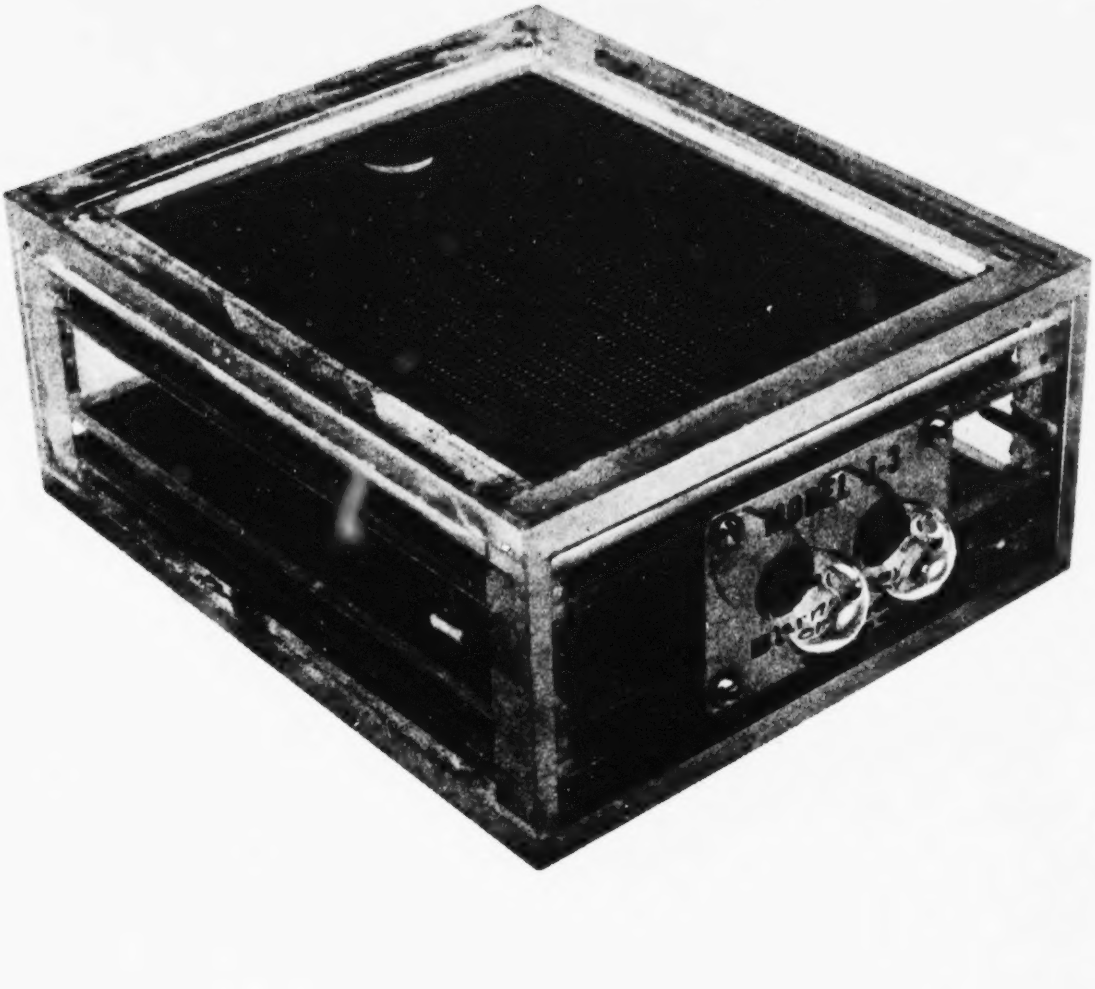
Vapor Dilution Technique. Vapor dilution is the most commonly used form of sensory analysis. The normal scope of procedure entails the sampling of an odorified atmosphere, adjustment of odorant concentrations in the sample by dilution or concentration, and presentation of the adjusted sample to a single observer or panel of observers for evaluation of the threshold odor concentration. Vapor dilution techniques can be static, continuous, or entail volatilization, depending upon the manner in which the sample is presented to the observer.

The vapor dilution technique of foremost interest to this study utilized the scentometer, a continuous technique device. The scentometer is of interest because it combines the sampling and analysis function into a single utilitarian unit (shown in Figure 1). The device was developed by Norman A. Huey and his colleagues in the late 1950's and was subjected to considerable evaluation before its introduction into the commercial market.[2] The fundamental purpose of the scentometer was to provide a ready tool for the measurement of ambient odor intensity to be used by field air pollution control inspectors as a means of documenting odor problems.

The scentometer functions by diluting ambient air samples with purified air and delivering the mixture to the olfactory tract for appraisal through two nose pieces, air being drawn through the instrument by the action of the observer's lungs. The various dilutions are supplied by a combination of critical size orifices for admission of ambient air to the mixing chambers of the scentometer. Purified air for dilution purposes is provided by the passage of ambient air through beds of activated carbon contained in the unit. The size of the unit is 5" x 6" x 2.5". The activated carbon unit used in the unit is reportedly serviceable for at least three months when the unit is subjected to daily use.

Figure 1

MODEL I-3 SCENTOMETER
BARNEBEY-CHENEY CO.



Under normal conditions of use, the observer breathes through a scentometer for a minute with all odorous air inlets closed. This period of time is to refresh or defatigue the observer. Then the small odorous orifice which gives the highest dilution is opened, and if no stimulus is obtained the next larger orifice is tried until a positive stimulus is obtained. The strength of the odor is designated as the dilution at which the observer can first perceive the odor.[3]

The utility of the scentometer is that it provides a rapid observation at a specific point in time and location. The observation so obtained is a function of three factors: the individual response to an odor stimulus, the effectiveness of the unit at the time of observation, and the ambient variability of the odorified atmosphere at the time of observation. The individual response is related to the observer's knowledge of odors and level of experience in interpreting the stimuli. His receptivity can vary on an hourly and diurnal basis from day to day and in response to physical and psychological variables in his daily life. The effectiveness of the unit is related to the degree of dilution achieved (in part, a function of consistent operator practice), the degree of odorant sorption/particle filtration on the activated carbon bed, and the degree of aggregation of the odorant. Ambient variability of odorant levels is related to the degree of instability of dispersion and circulation patterns in the atmosphere, to source variability, and in a broader sense to topographic and changing meteorology conditions. Within this framework of qualifications, the scentometer has found its most useful application under the following set of conditions:

(1) Day-to-day point evaluation of odor sources, with the instant readout providing an opportunity for rapid feedback to effect abatement, enforcement, etc., on the odor emitter where identifiable.

(2) General odor problem identification.

The scentometer was used in the technical field program of this study to accomplish general odor problem identification in areas having odor problem situations.

Sensory Evaluation Techniques. The principal developmental work in the area of sensory evaluation of atmospheric odors has been done by Amos Turk and Stanley Mehlman.[4] Because no system of universally understood odor quality descriptors or primary odors has yet been developed to describe the large variety of specific odor types encountered in polluted atmospheres, Turk devised an empirical approach to sensory evaluation that does not entail any assumptions concerning primary odor types. The key to Turk's approach is the use of quality descriptors that are represented by chemically defined odor quality reference standards. Quoting from Turk and Mehlman:[5]

> "In this method, the group of odors to be judged is defined in terms of a few (usually three to eight) qualities that seem reasonable in the light of subjective associations and chemical analysis. The

selections are made by people who are familiar both with the odors in question and with the analytical findings, even though the latter may be incomplete. Then an odor quality reference standard is made up to represent each quality description. The chemicals used in a reference standard represent the best choice available on the basis of odor, stability, lack of toxicity, and correspondence with constituents that are known or suspected to exist in the odorant. Each reference standard may then be expanded into a dilution scale using a suitable odorless diluent. For convenience and in order not to overload the judges' capacity for yielding informative responses, the number of points on the dilution scale should correspond to the following relationship: number of quality standard x number of intensity standards per quality = 12 to 36. Then an odor to be appraised may be described in terms of intensities of the various qualities by proper matching with the reference standards.

"The odor standards may be taken from the emission sources themselves. If the odor sources undergo chemical modification before they are released to the atmosphere, then the chemical modification may be simulated in the laboratory in making up the standard. Alternatively, an actual sample of the atmospheric discharge may be taken for the standard. The primary requirement for the odor standards is that the panel members must be able to distinguish them from each other and to relate each standard to the emission source which it represents."

The principal advantages of the foregoing method are that the program of sensory measurements can be related to the objectives to be met by appropriate selection of quality reference standards. The quality reference standards relate directly to the problem of concern and can be presented to the observer in a natural state for his training and memorization of intensity. The method has a broad mobility, a foremost utility of the method being in field applications oriented to the documentation of dispersion patterns from confined and unconfined source emissions. Odor intensity data correlative to the source of concern can be obtained by placing trained panelists on arcs increasingly distant from the source in the path of the dispersion pattern. Direct evaluations of two major odorant emitters in the Philadelphia area were carried out using precisely this approach.

TWO-DAY TECHNICAL FIELD INVESTIGATIONS

Two-day technical field investigations were planned and conducted, chronologically, in Portland, Kansas City, Cincinnati, Buffalo, Philadelphia, Tampa, and San Francisco. Three areas of activity were carried out in these surveys: administrative-level discussions, technical information documentation, and identification of specific neighborhood areas and districts where major odor problems occur.

The approach used in setting up the field investigations was to establish contact with state, regional, and local air pollution control agencies in each of these cities, using the liaison of NAPCA Regional Directors. The itinerary developed in this initial effort is presented in Table I. After an itinerary was established, a framework document outlining the objectives of the two-day visits was sent to each agency. During the meetings held in each two-day visit, the relevance of odor problems and extent of odor problem areas was identified through direct discussion with agency technical personnel immediately familiar with the problems. Information flows were documented with respect to agency response and to management of odor complaints, odor problem areas were visited, and street maps were sketched to indicate the extent and (using the scentometer) intensity of the odor problems.

A summary of the administrative discussions and technical documentation on odor problems available in the files of air pollution control agencies in the seven metropolitan areas investigated is presented in Chapter VI. Maps illustrating odor problem areas in each of the principal cities in these areas and meteorological data for the monthly period in which the scentometer readings were made are presented in Appendix E. The information descriptive of the odor problem situations in each of the cities is summarized in terms of the extent of areas affected by specific odor sources.

Areal Extent of Odors

Observations on the areal extent of perceptible odors in the cities listed above are summarized in Table II. Refinery installation and chemical facilities were found to be the most significant sources of odor emissions from the viewpoint of areal extent. The average area affected by odor emissions from a single refinery was 10 square miles, and that from chemical facilities, in excess of 5 square miles. The least significant sources, in terms of areal extent of odor impact, were rendering, paint and varnish, and tanning facilities. There is a correlation between the size of facility, category of source, and areal extent of odor impact. For example, refinery and chemical facilities are generally large complexes with a significant number of stacks and confined sources of odors, whereas rendering and the other facilities generally having the least areal impact are usually small facilities with unconfined or general odor sources.

Table I

ENGINEERING-SCIENCE, INC.
TECHNICAL FIELD PROGRAM ITINERARY

Dates	Metropolitan Area	Agencies Involved
September 18-19	Portland, Oregon	Columbia-Willamette Air Pollution Authority
September 22-23	Kansas City, Kansas-Kansas City, Missouri	NAPCA Region VI Division of Environmental Sanitation, Kansas City, Missouri, Health Department Air Pollution Control Division, Kansas City, Kansas-Wyandotte County Health Department
September 24-26	Cincinnati, Ohio	Cincinnati Division of Heating Inspection and Air Pollution Control
October 1-3	Buffalo, New York	Division of Air Resources, New York State Department of Health Air Pollution Control Division, Erie County Health Department Bureau of Air Pollution Control, Niagara County Health Department
October 6-7	Philadelphia, Pennsylvania- Camden, New Jersey	Division of Air Pollution Control, Pennsylvania Department of Health Division of Clean Air and Water, New Jersey State Department of Health Air Management Services, Philadelphia Department of Public Health
October 8-10	Tampa, Florida	Division of Environmental Engineering, Hillsborough County Health Department Manatee County Health Department
October 13-22	Philadelphia, Pennsylvania (sensory evaluation of odors studies)	NAPCA Division of Economic Effects Research
October 23	San Francisco, California	NAPCA Region IX Bay Area Air Pollution Control District

Table II

AREAL EXTENT OF PERCEPTIBLE ODOR
TWO-DAY TECHNICAL FIELD INVESTIGATIONS

Summary of Observations in the Principal Cities of Seven Metropolitan Areas

Type of Industry or Major Product	Number of Observations	Areal Extent (square miles)	
		Average	Range
Refinery	3	10	1.5 - 23
Agricultural Chemical	1	6	-
General Chemical	3	5	0.6 - 8.4
Polluted Bay	1	4	-
Sewage Treatment	1	2.5	-
Granary	1	2	-
Electrical	1	1.7	-
Tall Oil	1	1.25	-
Meat Packing	1	1	-
Rendering	4	0.8	0.2 - 1.3
Paint and Varnish	1	0.4	-
Tanning	1	0.1	

Source: Engineering-Science, Inc.

SENSORY EVALUATION OF ODORS: PHILADELPHIA STUDIES

The sensory evaluation studies in Philadelphia were carried out over a week-long period from October 14-20, 1969. The initial steps in the studies entailed the arrangement of laboratory and training facilities for preliminary screening and subsequent training of panelists to be deployed in the field sensory evaluations. Training facilities were leased from the University City Science Center, and laboratory facilities were made available in the Monel Institute, both institutions being affiliated with the University of Pennsylvania and located in Philadelphia. The training facilities room was of sufficient size to provide approximately fifty square feet of working space per trainee, which was adequate for purposes of this effort. The sequence and scope of activities were as follows:

(1) Triangle odor testing with food flavorings (almond, anise and lemon) to discern differences in odor sensitivity between panel members under laboratory conditions.

(2) Odor panel training sessions with odor quality reference standards, followed by field tests to ascertain odor emission dispersion patterns. Three field tests were done in the vicinity of two large refineries. Hexadecylmercaptan in mineral oil was used as a quality reference standard. An additional field test was done in the vicinity of a rendering plant. In this case, linseed oil diluted in mineral oil was used as the quality reference standard.

(3) Calibration runs were conducted to discern differences in odor sensitivity between panel members under field odor conditions. All panelists were located at the same sites during each run. One site was near two large refineries and the second site was near a rendering plant.

(4) Odor intensity rating tests were carried out as a cross check against the triangle odor tests to discern differences between panel members under laboratory conditions.

Methodology

Triangle Odor Tests. Eighteen candidates, recruited from the League of Women Voters, City of Philadelphia Chapter, were screened in a series of seven triangle odor tests on the first day of the sensory evaluation study. These tests were conducted according to procedures described by Janet Wittes and Amos Turk.[6] Three odorous solution samples were presented to a candidate at the same time; two were identical and one was different. The candidate was instructed to select the sample which was different from the other two and to record on a score sheet the code number of the sample chosen as odd. After the series of triangle tests were completed, the candidates were scored by the following procedure:

(1) The number of correct answers given by each candidate was listed in order, highest score first.

(2) The difference between two candidates in the number of correct answers was correlated with the probability that at least the difference could have been obtained by chance.

(3) A decision was made as to the number of panel members required from the candidates available.

(4) A criterion was selected at which the difference between candidates was deemed statistically significant (rather than due to chance alone). Statistical significance was defined in terms of confidence limits.

Aqueous solutions of almond and lemon extracts and anise were used in the triangle tests. The samples were prepared by diluting each odorant approximately to its threshold level.

Odor Panel Training Sessions. Odor panel training sessions were conducted in the mornings prior to each of the four field tests. Two sets of odor quality standards were prepared in four dilutions, each to provide the panelists with a means of familiarizing themselves with the odors prior to the field activities. Concentrations were selected empirically to approximate the range of odor intensities encountered in the field. Hexadecylmercaptan diluted into mineral oil at 0.05, 0.0125, 0.00313, and 0.0078 percent by volume was used to prepare the standards simulating refinery odorant emissions. Undiluted linseed oil and linseed oil diluted into mineral oil at concentrations of 25, 6.25, and 1.56 percent were used to simulate rendering plant odorant emissions. The quality reference standards were prepared in 1-oz. amounts in 4-oz. flexible plastic bottles. Panelists were instructed to shake each bottle, remove the cap, squeeze the sides, and sniff the resulting vapor. By repetition and concentration, the panelists were able to memorize the intensities of each of the four dilutions for later reference under field conditions.

Field Sensory Evaluations. The field sensory evaluations were conducted at two locations using all eighteen of the original candidates as panelists. (As explained below, none of the candidates were rejected on the basis of insensitivity to odors.) On each of the four occasions the candidates were placed randomly in the field. No effort was made to locate any of the panelists at the same site twice.

On each of the field odor evaluations, the panelists were instructed to commence recording odorant intensities at the same time and to record their observations at thirty-second intervals for 20 to 30 minute periods.

The two areas selected for sampling were:

(1) An area bounded by Vare Street, Dickinson Street, and 29th Street, located northeasterly one-eighth to one mile from the refinery complexes of Gulf Oil Company and Atlantic-Richfield Oil Company in southeastern Philadelphia. This neighborhood contains primarily lower middle-class two-story row houses in a predominately black neighborhood.

(2) An area bounded by Interstate Highway I-95 and the North Sewage Treatment Plant, located generally easterly of Keystone Rendering, Inc., and Mutual Rendering, Inc., in northeastern Philadelphia. The neighborhood can be classified as primarily lower-class two-story row houses and frame houses, many of which have been abandoned, and is mixed racially.

The two areas are shown on the locational map of Appendix E, Figure E-5. The neighborhood adjacent to the refineries is located at the northeasterly edge of the Plain of Confluence of the Schuylkill and Delaware Rivers, and is about four miles northeast of Philadelphia International Airport. The neighborhood in which the rendering facilities are situated is located on the west bank of the Delaware River about 12 miles northeast of the Philadelphia International Airport.

Calibration Runs. One calibration run was carried out in each of the areas studied in the field sensory evaluations. The calibration runs were conducted by stationing all panelists in the same area of the dispersion pattern of odorant emissions from the refineries and the rendering plants. The panelists began recording odorant intensities simultaneously and recorded their observations on half-minute intervals for 20 minutes. Scentometer readings were taken by an ESI engineering team member at recorded time intervals during the 20-minute periods.

Odor Intensity Rating Tests. Odor intensity rating tests were conducted at the end of the field sensory evaluations and calibration runs to provide a check of panelist proficiency in odor intensity memorization which could be compared with the triangle tests. Intensity rating tests were conducted according to procedures described in Wittes and Turk.[7] The test consisted of setting up a series of four dilutions of quality reference standards. The panelist was given one of the four standards and asked to identify its intensity.

Two series of odor intensity rating tests were given, one with the refinery odor standards and the second with the rendering plant standards. In each test the previously described dilutions were used for each standard. Each series consisted of six individual tests in which the panelist was requested to replace the dilution of standard removed from the series back into the sequence of dilutions. The panelists were scored by the same procedure discussed previously for evaluation of results of the triangle odor tests.

Results

Triangle Odor Tests. The data developed in the seven triangle odor tests are presented in Appendix F. The results of statistical analysis of these data are presented in Table III and illustrated in Figure 2. As reported in Table III, six of the eighteen candidates had six of seven answers correct, three had five correct answers, four had four correct answers, three had three correct answers, and no results were obtained for two candidates (Numbers 9 and 16). The number of acceptable candidates can be obtained by selecting the confidence limits at which the difference in scores between candidates is deemed insignificant. Figure 2 shows a plot of number of candidates accepted versus confidence limits, where the confidence limits were taken as the probability that at least the difference could have been obtained by chance. Based on this criterion, fifteen panelists would have been accepted at the 10 percentile confidence limits, nine at 50 percent, three at 90 percent, and two at 95 percent.

For rough screening purposes, Wittes and Turk recommend that confidence limits be set at about 25 or 30 percent in order to effect the initial rejection of a large proportion of the candidates that are likely to be unsuitable.[8] At confidence limits of 30 percent, only twelve of the eighteen candidates would have been accepted. Because of the difficult circumstances under which the candidates were obtained, no candidates were rejected on the basis of the triangle tests. On the basis of the odor intensity rating tests discussed below, it was observed that no correlation existed between poorly performing candidates in one test and in the other. In fact, several candidates who performed poorly in one test did well in the other.

Odor Intensity Rating Tests. The data developed in the odor intensity rating tests are presented in Appendix F. The results of statistical analysis of these data are summarized in Table IV and in Figure 2. The results of these tests reflect the experience of several days of training sessions and field surveys. There is a basic similarity in the results obtained from tests with both of the quality reference standards. Panelist No. 10 performed poorly in both intensity rating tests (Table IV), whereas Panelist No. 13 performed well in the rendering standard testing but poorest in testing with the refinery standard. Panelist No. 13 was one of the best panelists participating in the triangle tests (Table III), whereas Panelist No. 10 performed with mediocrity in the triangle tests. These results indicate the rather random performance by candidates, depending on the type of test. Only one panelist, No. 10, was a consistently poor performer. Because of the general lack of correlation between performance levels of candidates by either of the tests, all candidates were accepted as panelists and used randomly in the field sensory evaluations.

The correlation between number of acceptable panelists and confidence limits at which the difference in scores between panelists is deemed insignificant is shown in Figure 2. At the 30-percent confidence limit fourteen of the panelists were acceptable by either of the tests. Generally, the curves for the refinery odor testing paralleled that for the rendering odor, but both of these curves indicated that more candidates were acceptable in the 30 to 70 percent confidence limit range by the odor intensity rating tests than by the odor triangle tests. It is believed that the experience gained by the panelists in the six-day time interval between the triangle tests and the intensity rating tests is a significant factor explaining the better performance of the panelists in the latter tests.

Table III

ANALYSIS OF TRIANGLE TEST RESULTS

Candidates	Number of Correct Answers	Difference In Number of Correct Answers	Probability That At Least Difference Could Have Been Obtained By Chance (percent)	Panelists Accepted (Total)
-	7	-	100	0
4, 18, 1, 11, 8, 13	6	0	78	6
6, 7, 12	5	1	39	11
2, 10, 14, 15	4	2	15	15
3, 5, 17	3	3	4	18

Source of procedure for statistical analysis: Amos Turk and Janet Wittes, "The Selection of Judges for Odor Discrimination Panels," Correlation of Subjective-Objective Methods in the Study of Odors and Taste, Special Technical Publication No. 440 (American Society for Testing Materials, 1968).

Table IV

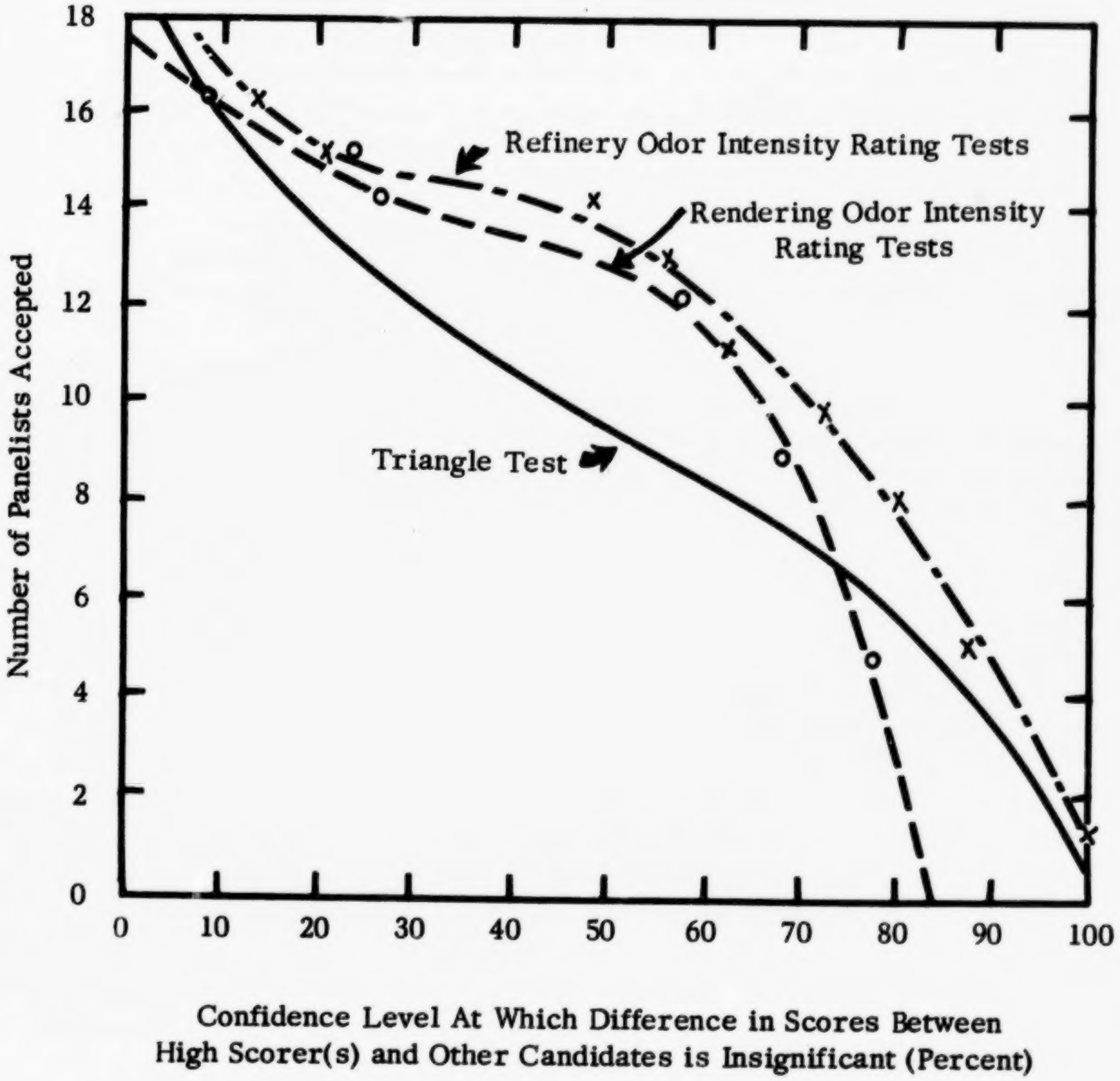
ANALYSIS OF ODOR INTENSITY RATING TESTS

Candidate	Score (Highest Score Reflects Worst Performance)	Probability That At Least Difference Could Have Been Obtained By Chance (percent)	Panelists Accepted (total)
Refinery Quality Reference Standard			
5	0	100	1
1, 2, 11, 14	1	87	5
3, 15, 18	2	79	8
6, 8	3	71	10
16	4	63	11
7, 9	5	56	13
4	6	-	14
-	7	-	-
-	8	-	-
-	9	-	-
-	10	-	-
10	11	22	15
-	12	-	-
13	13	15	16
Rendering Quality Reference Standard			
-	0	100	-
-	1	86	-
7, 9, 11, 13, 18	2	77	5
2, 5, 6, 16	3	68	9
3, 4, 8	4	59	12
14, 15	5	30	14
1	6	25	15
-	7	20	-
-	8	16	-
-	9	13	-
10	10	10	16

Source of procedure for statistical analysis: Amos Turk and Janet Wittes, "The Selection of Judges for Odor Discrimination Panels," Correlation of Subjective-Objective Methods in the Study of Odors and Taste, Special Technical Report No. 440 (American Society for Testing Materials, 1968).

Figure 2

SCREENING TESTS FOR SIGNIFICANT DIFFERENCE IN PERFORMANCE



Source: Engineering-Science, Inc.

Field Sensory Evaluation of Refinery Odor Emissions. Dispersion patterns for odorant emissions in the neighborhood of the refineries are plotted in Figures 8 through 13 for each of the three field sensory evaluations done in the area. The three runs were carried out on October 16, 1969 at noon and 3:00 p.m. and on October 17 at 1:00 p.m. Weather observations during each of these monitoring periods are reported in Table V, as recorded at the Philadelphia International Airport, located about four miles southwest of the Vare Street study area across the broad flat plain at the confluence of the Schuylkill and Delaware Rivers (see Appendix E, Figure E-5). It is assumed that airport data were applicable in describing weather conditions at the monitoring site.

Dispersion patterns for odorant emissions in the vicinity of the rendering plants are plotted in Figures 14 and 15 for the field sensory evaluation done on October 17, 1969 at 1:00 p.m. Weather observations from the Philadelphia International Airport during this monitoring period are also presented in Table V. The Philadelphia International Airport is located about 12 miles southeast and on the same (west) bank of the Delaware River as the area in which the rendering facilities are located. It is assumed, because of the topographical continuity between the airport and the neighborhood of the rendering facilities, that airport weather data were indicative of weather conditions at the monitoring site.

Dispersion patterns are plotted in Figures 8 through 15 using two types of contours: those based on the mean intensities of the observations of the individual panelists, and those based simply on the percent of the total observations of each individual in which odor was perceived.

Figures 8 and 9 illustrate clearly the first dispersion pattern developed for refinery odor emissions. The contours point to the location of a major emission source westerly of Morris Street and a generally unconfined source paralleling Vare Street. The dispersion pattern in Figure 9 indicates generally the presence of a second source southwesterly of New Hope Street. The 100 percent contour parallels the 3 MIU (mean intensity unit) contour on Morris Street, and the 80 percent contour is similarly paralleled by the 2 MIU contour. The 0.50 MIU contour extending along Tasker and 30th Streets is somewhat correlative with the 40 percent contour. Based on this observation, it appears that the MIU contours and the percentile contours both provide a basis for describing the extent, but not the magnitude, of the dispersion pattern.

Figures 10 and 11 illustrate dispersion patterns for a second run at the refinery area done about three hours after the first runs (on October 20, 1969). The wind direction had changed from 200 degrees previously to 190 degrees, as was evidenced by the different dispersion patterns observed in the second run. The contours in both Figures 10 and 11 point to two distinct sources of odor emissions, one due westerly of Morris Street and the second southwesterly of New Hope Street. The greatest MIU contours are 3 at Morris Street and 2 at New Hope and Vare Streets. The MIU contours decrease rapidly to less than 1 within 1,000 feet of Vare

Calibration Runs. Data developed in the calibration runs represented an opportunity to evaluate the variability of response of the panel members under conditions of an ambient odor environment. The observation sets developed by each individual in each run were analyzed for mean value. These sets of information have been analyzed as a basis for characterizing the performance variability of the panelists. A histogram for the mean intensities developed in the mercaptan calibration run is presented in Figure 3. A similar histogram for mean intensities developed in the rendering calibration run is presented in Figure 4. Each figure contains the following information on the histogram depicted: mean and median value of distribution, maximum frequency (number of panelists occurring in the range of mean observations or sample size), and the intensity at which the maximum frequencies occurred.

The mean and median intensities observed by the panelists as a group were, respectively, 2.34 and 2.88 for the mercaptan calibration run (Figure 3). Three individuals had mean intensity observations of 3.25. The mean intensities of the individuals were grouped into two sets, one set varying between mean intensities of 0.50 to 1.25, the second between 2.25 to 3.75. The mean intensity of all panelists for the rendering calibration run was 2.23 and the median intensity was 2.50 (Figure 4). Three individuals had mean intensity observations of 2.00, and three additional individuals had mean intensity observations of 2.75. It is apparent from comparison of the histograms in Figures 3 and 4 that the distribution of mean intensities in the rendering run was much more proximate to a normal Gaussian distribution than was the distribution of mean intensities observed in the mercaptan. On the basis of these histograms, it is apparent that the five panelists in the mercaptan runs with mean intensities varying between 0.50 and 1.25 responded at significantly lower levels than did their eleven counterparts with mean intensities of 2.25 to 3.75. There is no immediate explanation for this unexpected division other than that a similar but less defined spread was observed in the laboratory odor intensity rating tests reported in Table IV.

Based on the above analysis of the calibration runs and the previous discussion of the laboratory odor intensity rating tests, it is apparent that both the laboratory and field testing with the mercaptan provided a more stringent evaluation of individual capabilities than did the rendering odor tests.

Figure 3

HISTOGRAM FOR MERCAPTAN CALIBRATION RUN
- MEAN INTENSITY -

Total Data Points = 16

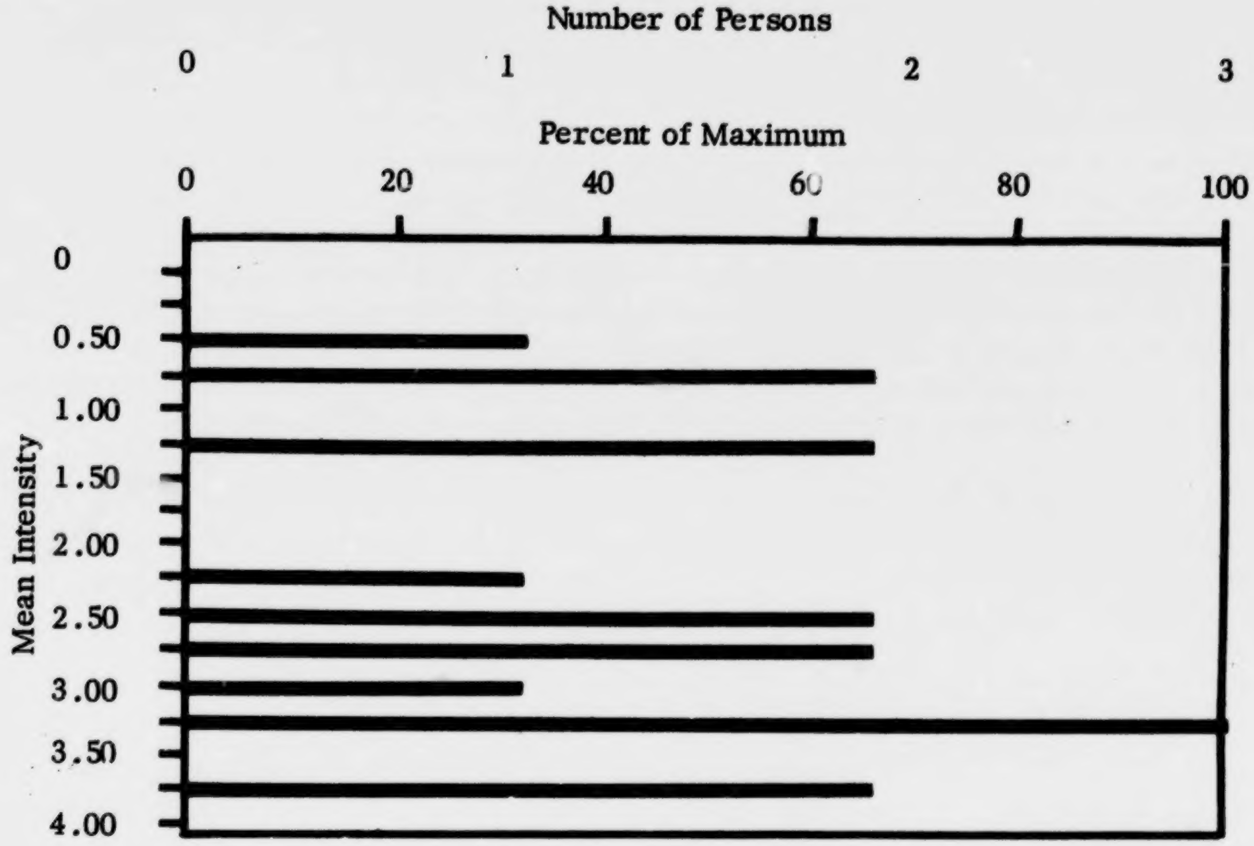
Sample Size = .25

Mean = 2.34

Median = 2.88

Maximum Frequency = 3

Maximum Frequencies at: 3.25



Source: Engineering-Science, Inc.

Figure 4

HISTOGRAM FOR RENDERING CALIBRATION RUN
- MEAN INTENSITY -

Total Data Points = 16

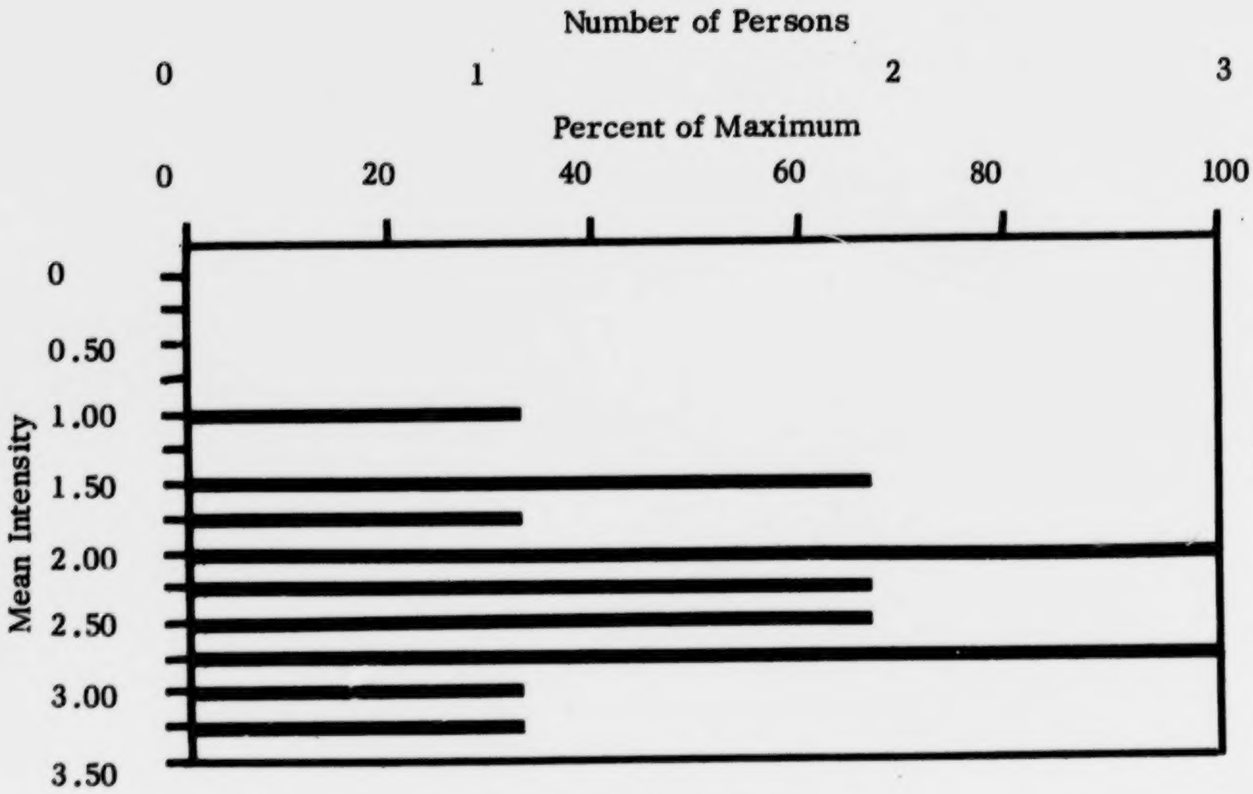
Sample Size = .25

Mean = 2.23

Median = 2.50

Maximum Frequency = 3

Maximum Frequencies at: 2 and 2.75

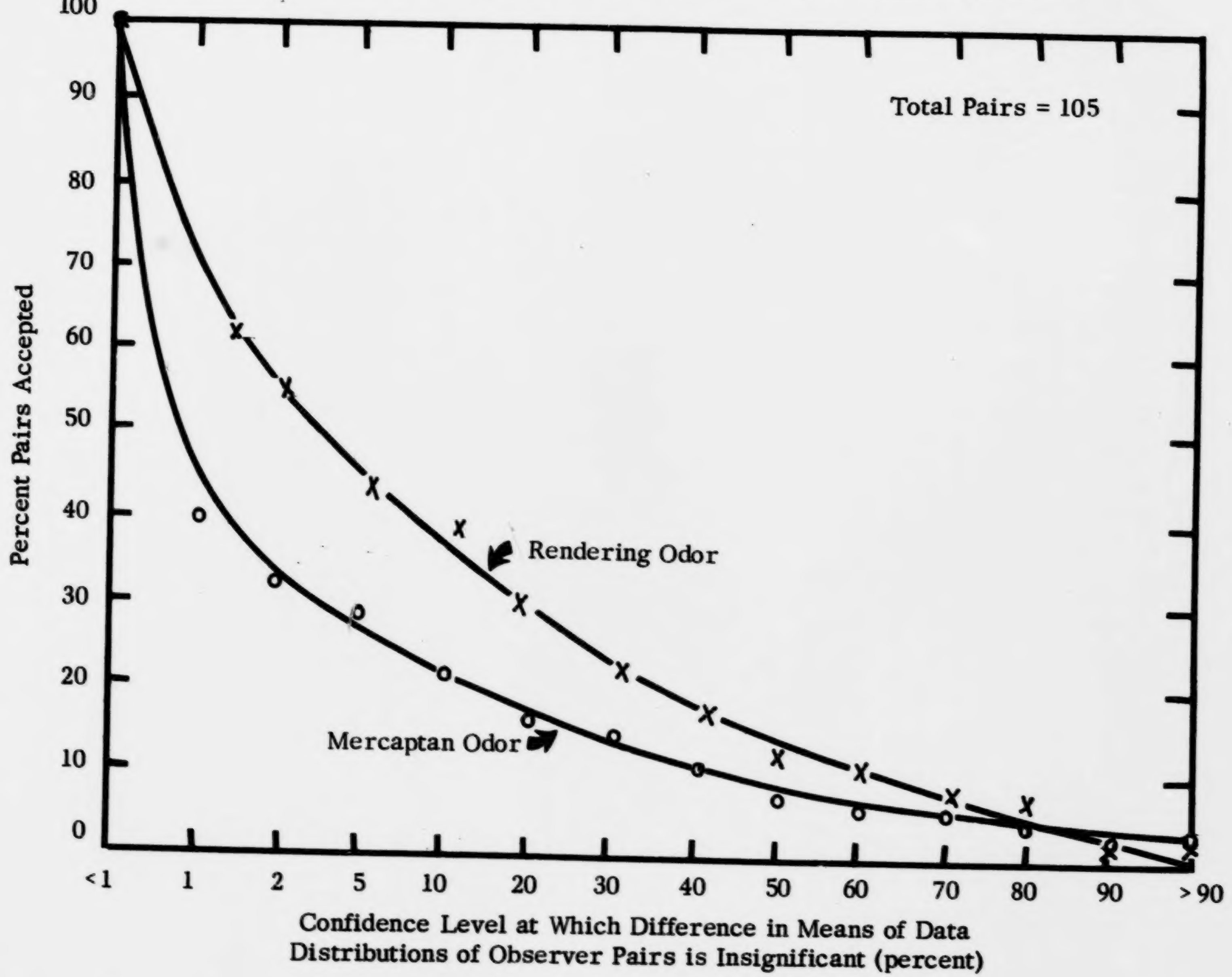


Source: Engineering-Science, Inc.

Additional statistical analysis of the calibration runs was done to determine the number of panelists performing at the same level of intensity observation over a range of confidence limits. A matrix of "t" statistics was developed to compare the statistical significance of the difference between the data distributions of all pairs of observers. The matrix contained 105 pairs of observations. Figure 5 shows the relationships between the number of observer pairs and the confidence limits at which the difference in performance levels of the individual would be statistically insignificant. At a confidence limit of 90 percent, only two percent of the observer pairs tested with the rendering odor and three percent of the pairs tested with the mercaptan odor could be accepted by this criterion. At confidence limits of 50 percent the acceptance levels increased to 14 percent with the rendering odor and eight percent with the mercaptan odor. At confidence limits of 30 percent, the acceptance levels increased to 23 percent with the rendering odor and 14 percent for the mercaptan odor. It is apparent from a comparison of relationships presented in Figures 2 and 5 that the calibration runs were a much more severe test than the laboratory tests in that a much lower level of acceptance is obtained at a given confidence limit when observer pairs are evaluated under field conditions rather than individual panelists under laboratory conditions. It is also apparent from Figure 5 that the panelists participating in the calibration runs had considerably more difficulty with the mercaptan odors than with the rendering odor. The opposite effect was observed with the intensity rating tests (Figure 2) in which the individual panelists performed slightly better with the mercaptan odors than with the rendering odor.

Figure 5

t TEST OF SIGNIFICANCE IN DIFFERENCE IN FIELD ODOR CALIBRATION RUNS MEANS OF DATA DISTRIBUTIONS BETWEEN OBSERVER PAIRS



Source: Engineering-Science, Inc.

Scentometer readings were also made during the calibration runs. These readings are plotted against mean panel odor intensities for the mercaptan odor in Figure 6 and for the rendering odor in Figure 7. The best-fit lines (least-squares method) correlating the scentometer and mean panel readings are described by the following equations:

Mercaptan odor: $S = 1.69\ P - 2.62$ (Equation 1)
Rendering odor: $S = 2.63\ P - 4.87$ (Equation 2)

where:

S = scentometer reading at time t
P = mean panel odor intensity at time t

The spread in mean odor panel observations at each of the scentometer readings is caused by two factors:

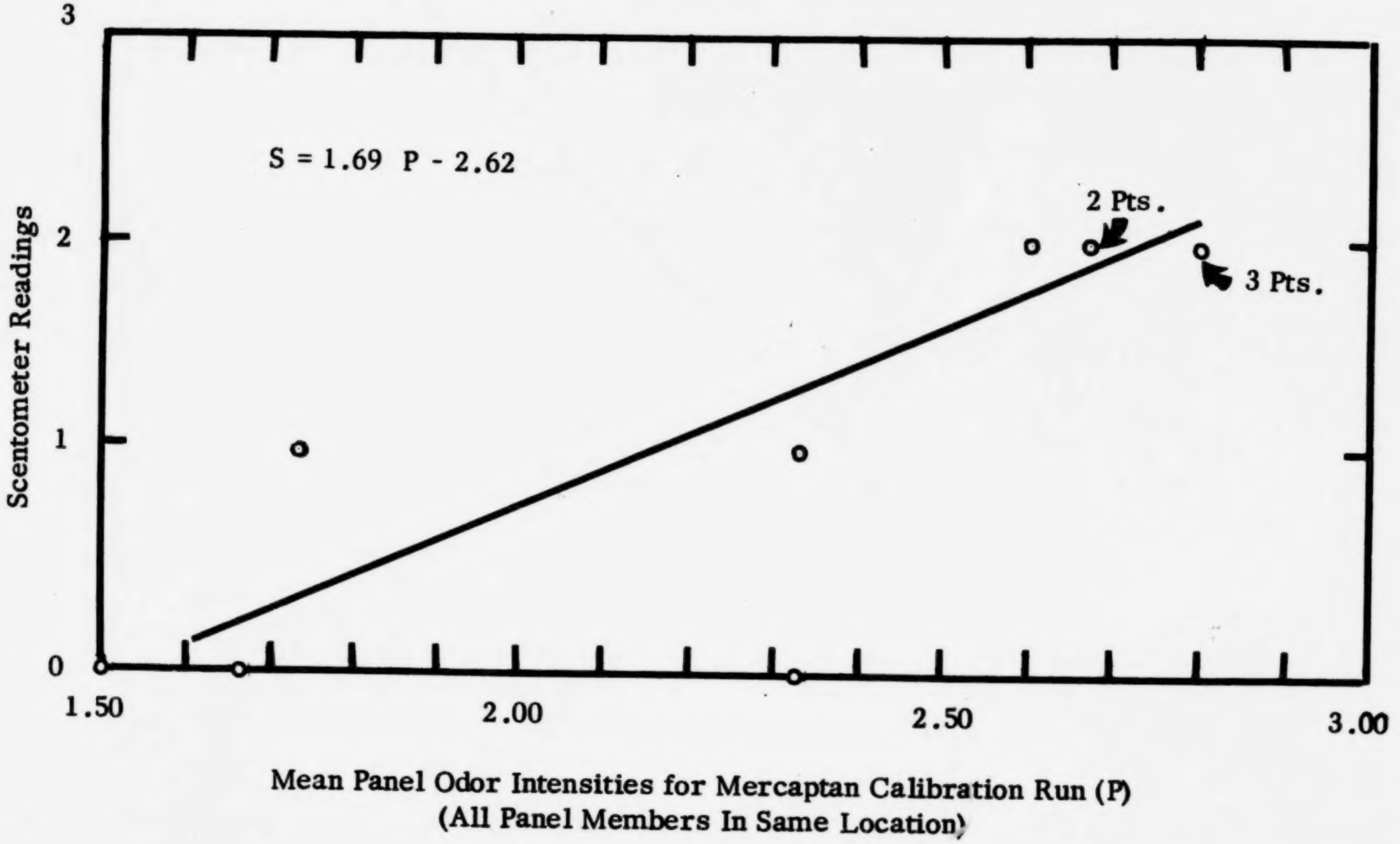
(1) The sensitivity of the scentometer differs significantly from the aggregate direct sensory response of the panelists as intensity of odor is varied.

(2) Single scentometer readings were made for each set of panelist responses used to calculate mean intensities. The single scentometer reading is subject to individual response variabilities as discussed in Chapter II. Within these qualifications Equations 1 and 2 provide a tool for conversion of intensity readings made by the panelists (trained with the above-described quality reference standards) into equivalent scentometer readings.

Equations 1 and 2 indicate that at low panelist readings the scentometer lacks the sensitivity of readout that can be provided by panels (as evidenced by the negative y-intercepts of these equations). From the viewpoint of ambient odor intensity monitoring, an aggregate responsiveness to low level odor intensities is a foremost requisite, and it is apparent from the calibration runs that direct sensory evaluation with a team of panelists can provide a useful level of sensitivity in those instances where it is required.

Figure 6

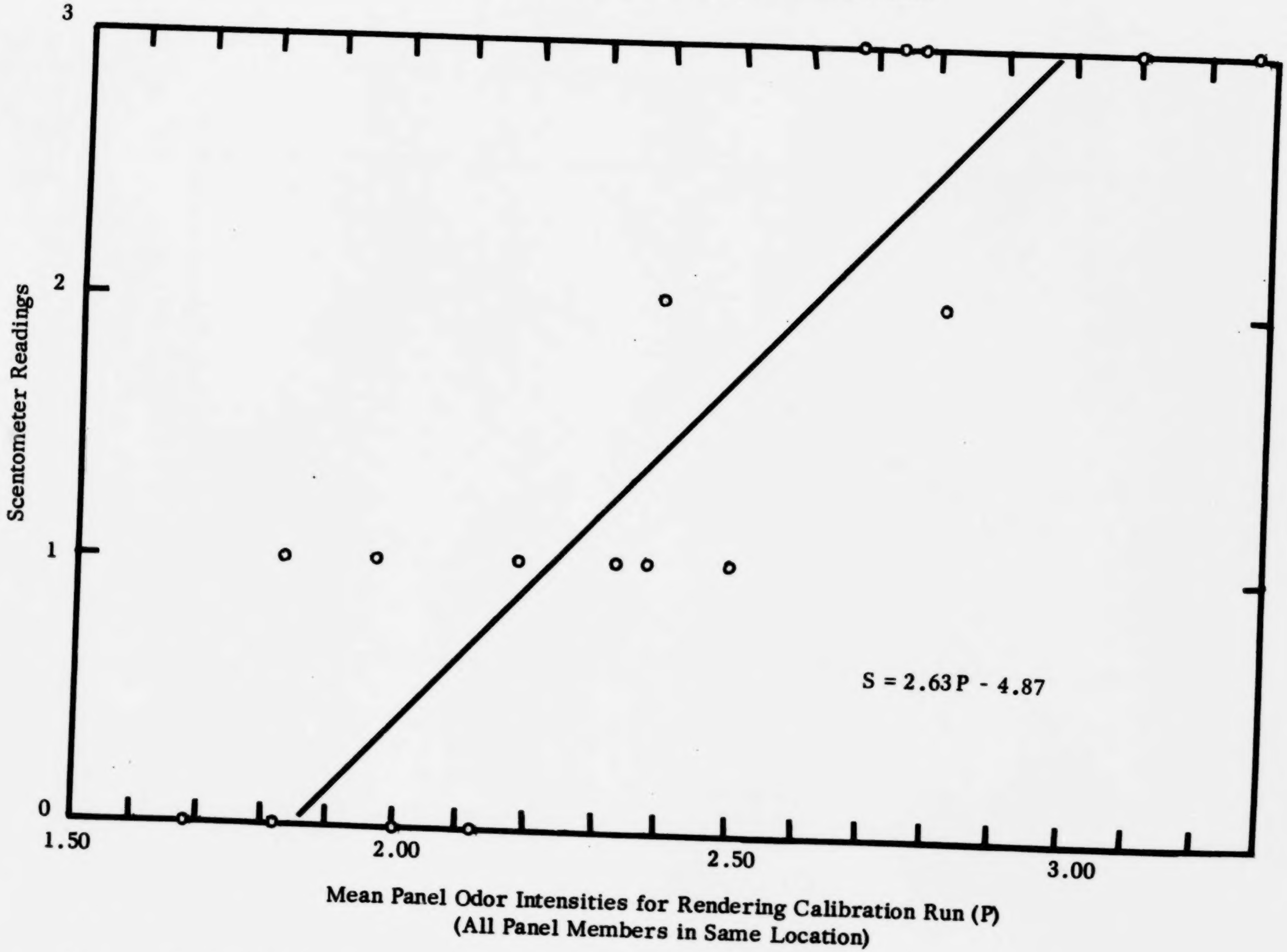
COMPARISON OF SCENTOMETER AND ODOR PANEL DATA
FOR MERCAPTAN CALIBRATION RUNS



Source: Engineering-Science, Inc.

Figure 7

COMPARISON OF SCENTOMETER AND ODOR PANEL DATA
FOR RENDERING ODOR CALIBRATION RUN



Source: Engineering-Science, Inc.

Street (Figure 10). The percentile contours (Figure 11) were maximal at 80 percent in the vicinity of Mifflin and Vare Streets and along Morris Street. The percentile contours do not parallel the MIU contours as was observed in the first run; the 60 and 80 percent contours extend easterly along Morris Street to 29th Street. It appears from these results that the intensity level and frequency of occurrence of odor perception did not correspond in the second run as occurred in the first run.

Figures 12 and 13 show dispersion patterns for the third run at the refinery area done four days after the first and second runs. The wind direction on the day of the third run was to the northeast (240 degrees), and the wind speed was 12 knots or twice that of the day of the other runs. The contours of Figures 12 and 13 identify two discrete sources as noted previously. The maximum MIU contours were 2 along Vare Street near Morris Street as well as at New Hope and Vare Streets. the MIU contours decreased to 0.5 MIU within 1,000 feet of Vare Street. As was the case in the first run, the percentile contours of Figures 12 and 13 paralleled generally the MIU contours. The maximum percentile contour was 100 percent at Vare Street near Morris Street areas and 80 percent along Vare Street between New Hope and 29th Streets. In this run, the percentile and MIU contours both provided a similar basis for describing the extent of the dispersion pattern.

Figures 14 and 15 illustrate the dispersion pattern observed in the neighborhood of the rendering facilities on October 17, 1969. The wind direction was from the northwest and the wind speed was 14 knots. The dispersion patterns evidence clearly the locations of the sources. The maximum MIU contour of the easterly plant (Figure 14) was 2; the maximum MIU contour relative to the westerly facility (located outside of the survey area) was 1. The maximum percentile contour was 100 percent at the easterly plant (Figure 15) and 80 percent relative to the westerly plant. The MIU contours and percentile contours generally paralleled each other and both provided a basis for establishing the extent of the dispersion pattern.

The field sensory evaluations described above provide weighty evidence for the utility of the sensory evaluation technique as a means of identifying the extent and magnitude of the dispersion pattern of an odor emission when expressed in MIU units. The use of percentile contours in lieu of MIU units obviates the need for extensively training panelists in memorizing odor intensities. Although panelists are still required, no measure of odor intensity can be obtained when the parameter indicating the percent of time that an odor was perceived is used. The above study results indicate that the full-scale sensory evaluation technique for atmospheric odor measurement should have significant application in those special circumstances where legal liability or compliance questions require that an odor emission problem be documented in an explicit and defensible manner.

Table V

UNITED STATES WEATHER BUREAU OBSERVATIONS
PHILADELPHIA, PENNSYLVANIA, INTERNATIONAL AIRPORT
OCTOBER 1969

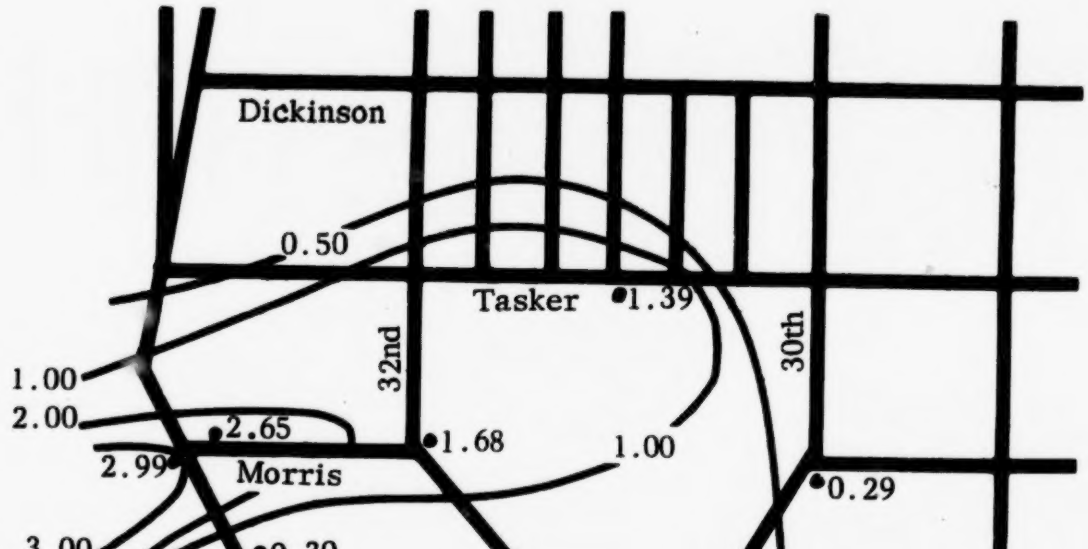
Date	Hour	Ceiling (feet)	Visibility (miles)	Wind Direction* (degrees)	Wind Speed (knots)	Dry Bulb Temperature (degrees F)	Relative Humidity (percent)	Notes
16	1 pm	8,000	8	200	6	61	63	-
16	4 pm	Unlimited	10	190	6	64	61	-
17	1 pm	10,000	10	290	14	60	46	-
20	10 am	Unlimited	5	240	12	66	63	Hazy, Smoky

* Wind originates from direction indicated, which is clockwise from true north.

Source: U.S. Department of Commerce. Local Climatological Data. Ashville, North Carolina: Environmental Science Services Administration, 1969.

Figure 8

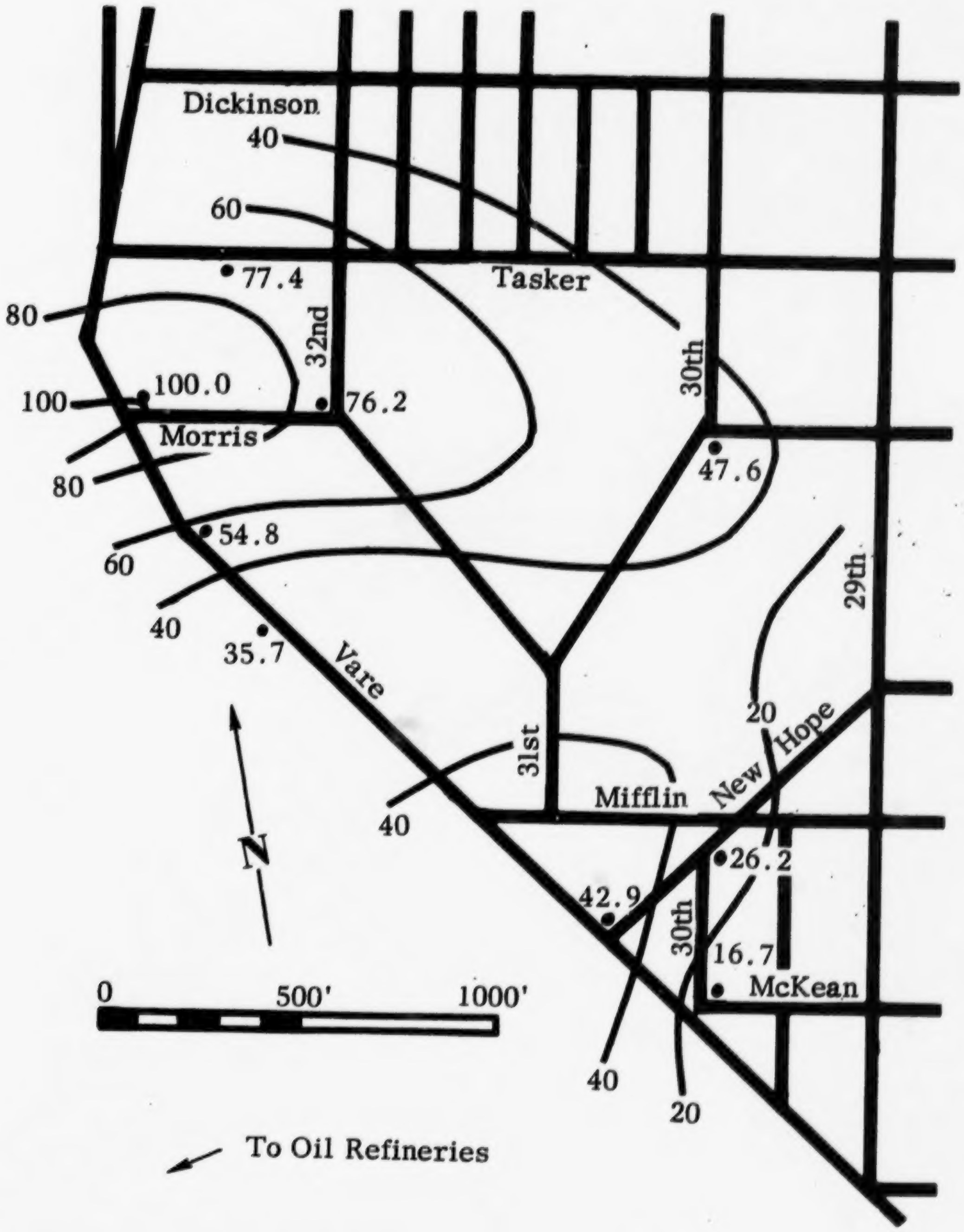
REFINERY ODOR EMISSION DISPERSION PATTERN NO. 1
(Contours based on mean odor intensities)


Dickinson
0.50
Tasker
1.39
32nd
30th
1.00
2.00
2.65
1.68
1.00
2.99
Morris
0.29
3.00
2.00
1.00
0.30
0.85
29th
0.50
Vare
31st
New Hope
N
Mifflin
0.56
0.494
30th
0.11
McKean
0
500'
1000'
To Oil Refineries

Source: Engineering-Science, Inc.

Figure 9

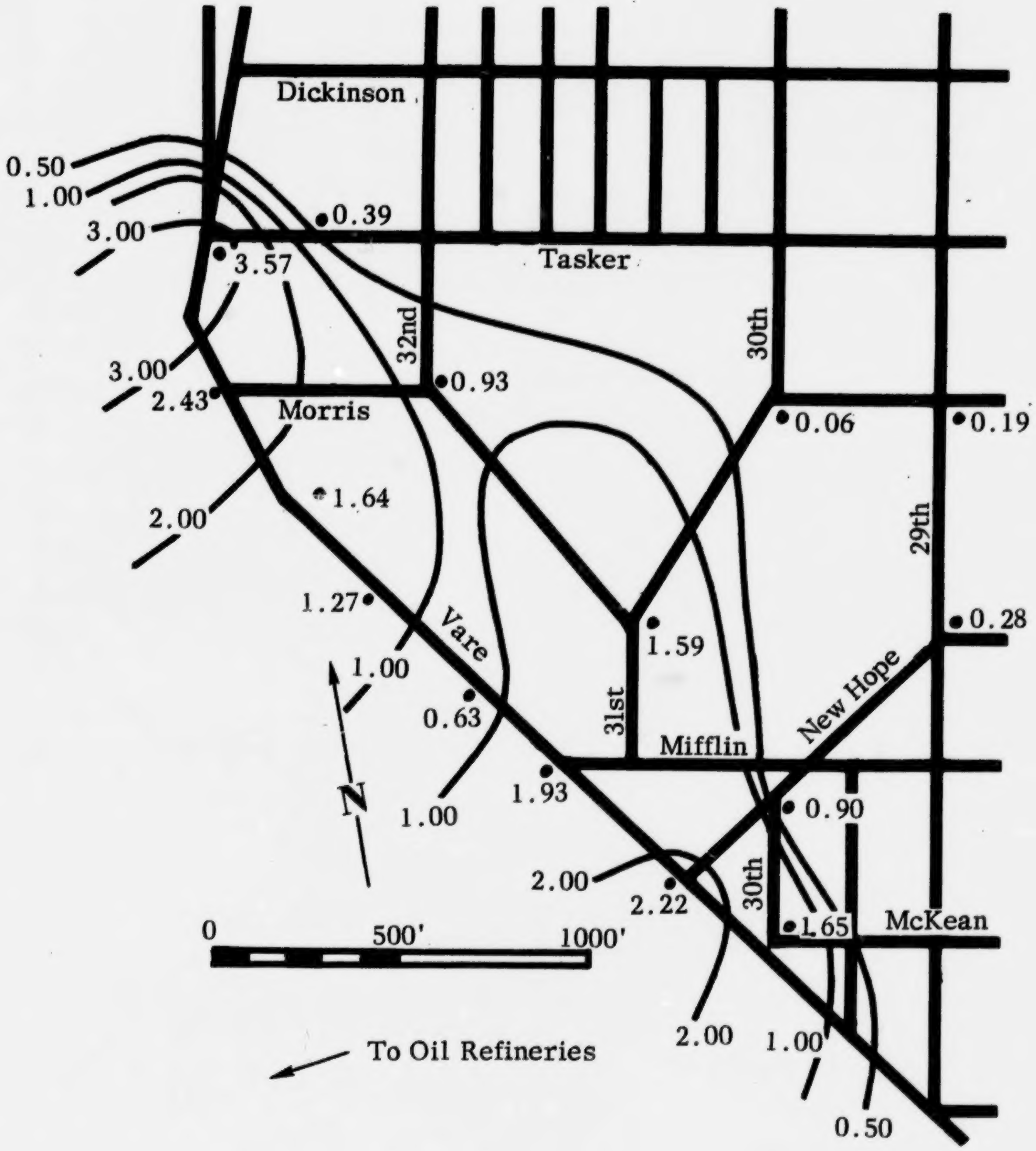
REFINERY ODOR EMISSION DISPERSION PATTERN NO. 1
(Contours based on percent of time odor was perceived)


Dickinson
40
60
77.4
Tasker
80
32nd
100
100.0
76.2
30th
Morris
80
47.6
54.8
60
29th
40
35.7
Vare
20
New Hope
31st
Mifflin
40
N
26.2
42.9
30th
16.7
0
500'
1000'
McKean
40
20
To Oil Refineries

Source: Engineering-Science, Inc.

Figure 10

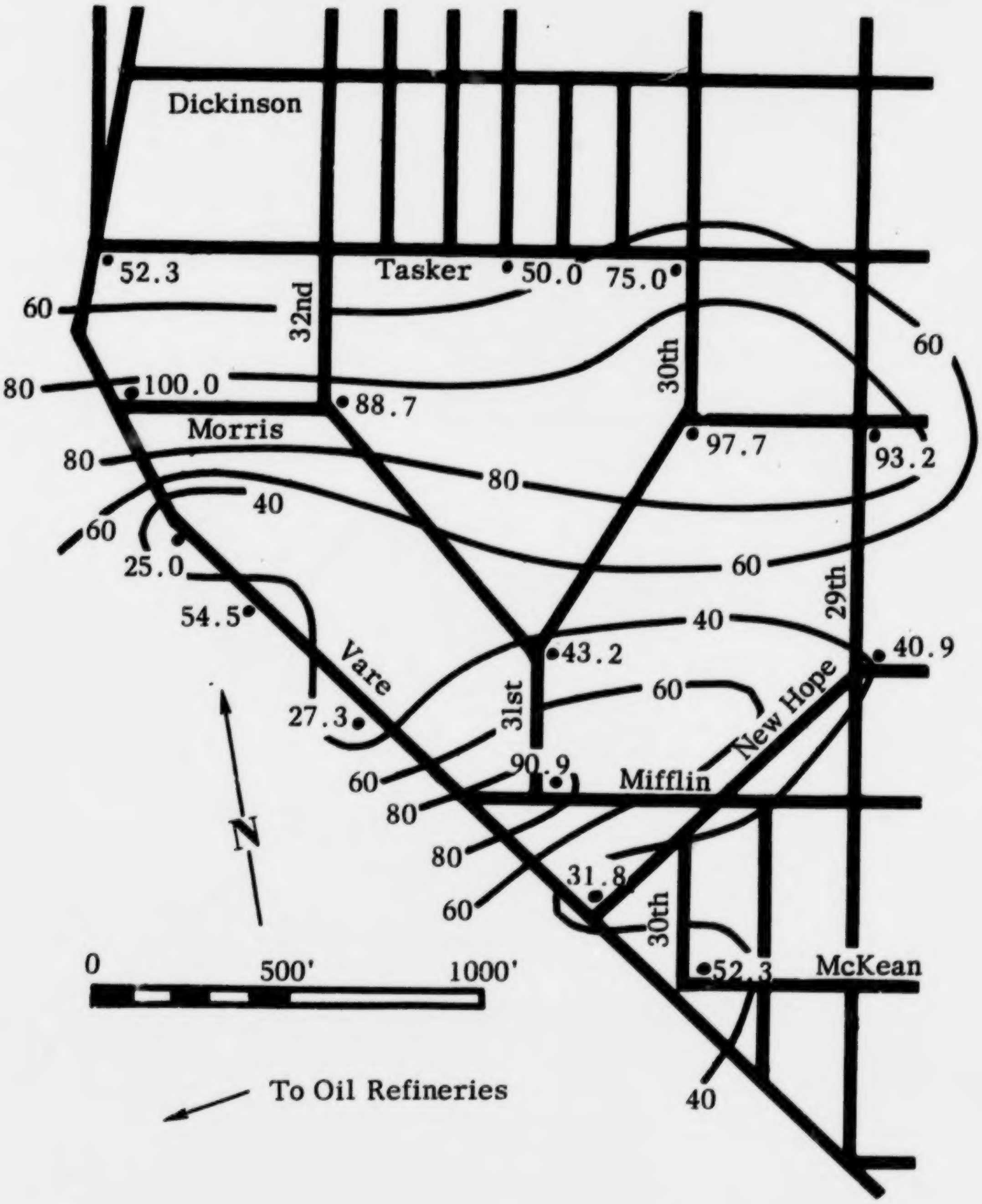
REFINERY ODOR EMISSION DISPERSION PATTERN NO. 2
(Contours based on mean odor intensities)


Dickinson
Tasker
Morris
Mifflin
McKean
32nd
30th
31st
29th
Vare
New Hope
0.50
1.00
3.00
3.00
2.00
1.00
1.00
2.00
2.00
1.00
0.50
0.39
3.57
0.93
2.43
1.64
1.27
0.63
1.93
2.22
1.59
0.06
0.19
0.28
0.90
1.65
N
0
500'
1000'
To Oil Refineries

Source: Engineering-Science, Inc.

Figure 11

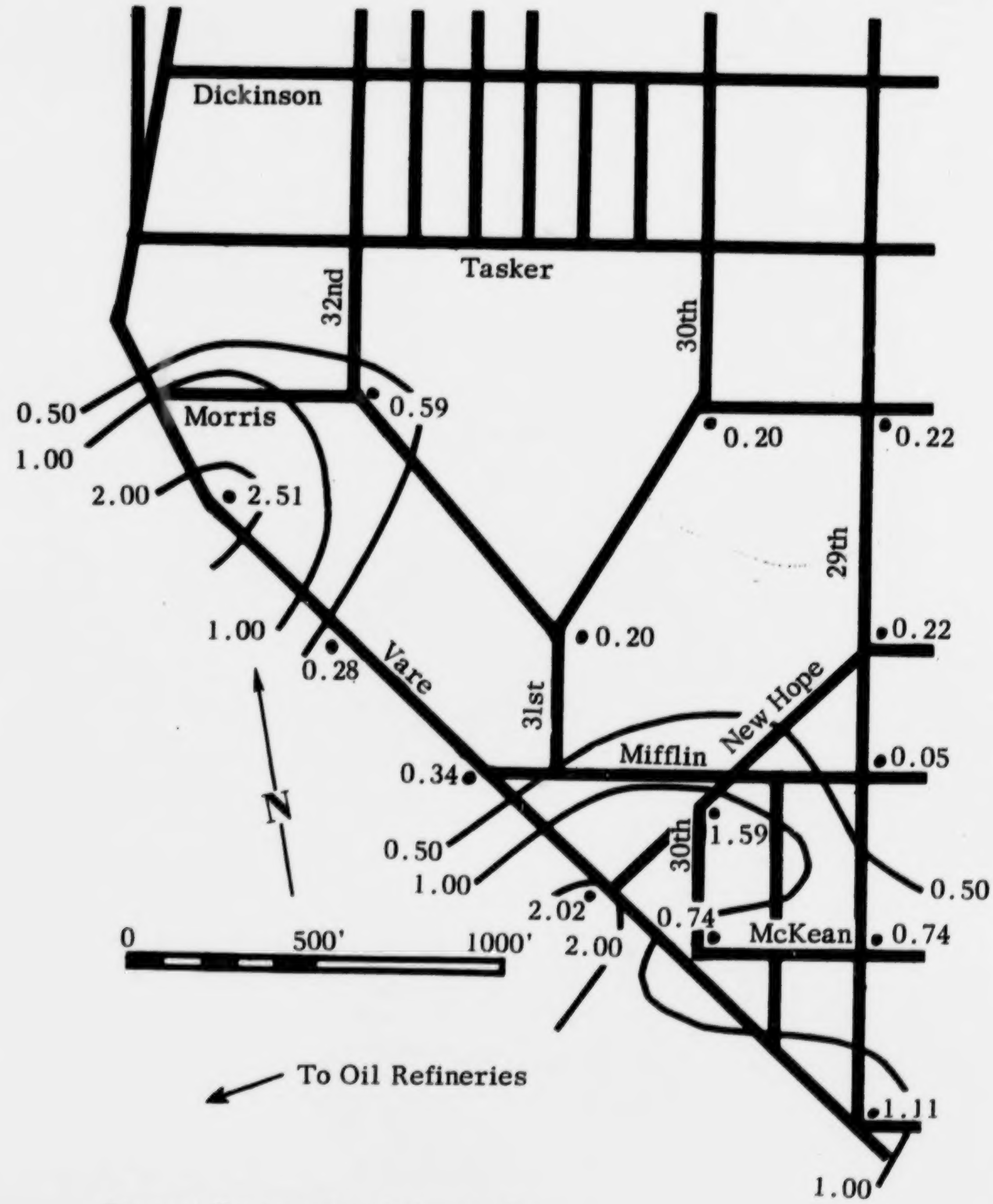
REFINERY ODOR EMISSION DISPERSION PATTERN NO. 2
(Contours based on percent of time odor was perceived)


Dickinson
Tasker
52.3
50.0
75.0
60
32nd
60
30th
80
100.0
88.7
Morris
97.7
93.2
80
80
40
60
25.0
60
54.5
29th
40
40.9
Vare
43.2
31st
60
27.3
New Hope
60
90.9
Mifflin
80
80
31.8
60
30th
N
0
500'
1000'
52.3
McKean
To Oil Refineries
40

Source: Engineering-Science, Inc.

Figure 12

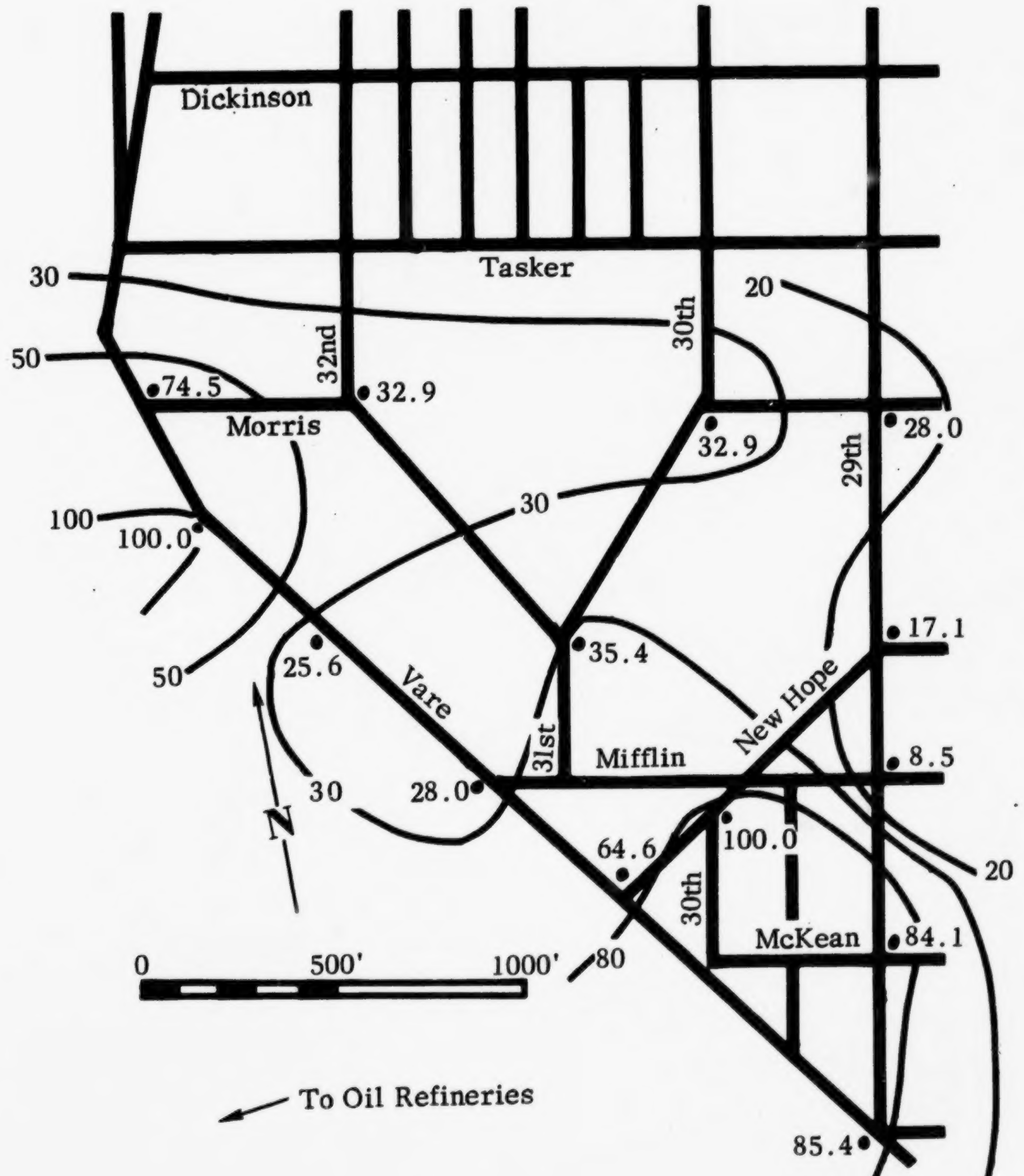
REFINERY ODOR EMISSION DISPERSION PATTERN NO. 3
(Contours based on mean odor intensities)


Dickinson
Tasker
32nd
30th
Morris
0.50
1.00
2.00
2.51
0.59
0.20
0.22
29th
1.00
0.28
Vare
0.20
0.22
31st
New Hope
Mifflin
0.34
0.05
N
1.59
30th
0.50
1.00
2.02
0.50
0.74
McKean
0.74
0
500'
1000'
2.00
To Oil Refineries
1.11
1.00

Source: Engineering-Science, Inc.

Figure 13

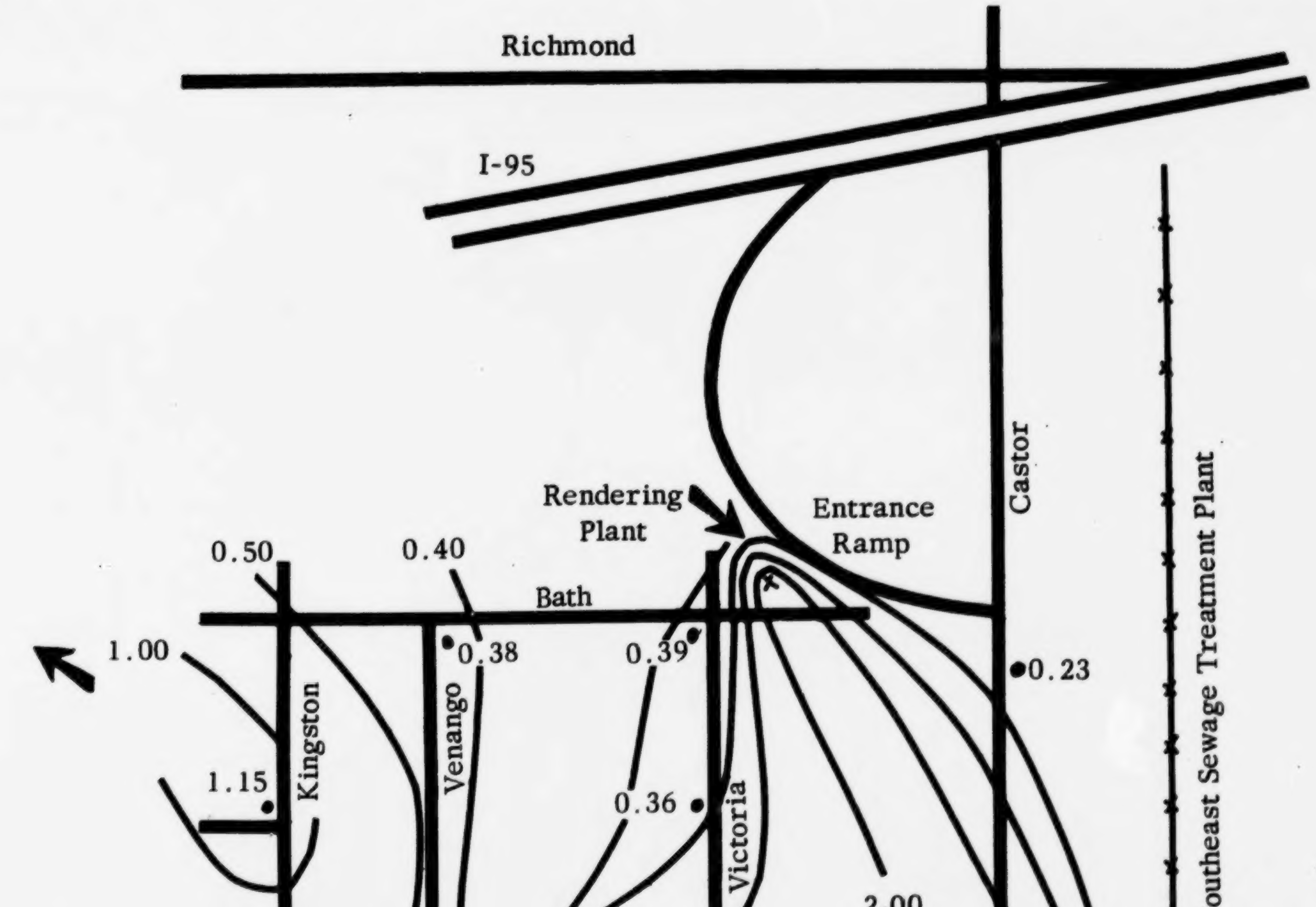
REFINERY ODOR EMISSION DISPERSION PATTERN NO. 3
(Contours based on percent of time odor was perceived)


Dickinson
Tasker
Morris
Vare
Mifflin
New Hope
McKean
32nd
30th
29th
31st
30th
30
50
100
50
30
30
20
20
80
80
30
74.5
32.9
32.9
28.0
100.0
25.6
35.4
17.1
8.5
28.0
64.6
100.0
84.1
85.4
N
0
500'
1000'
To Oil Refineries

Source: Engineering-Science, Inc.

Figure 14

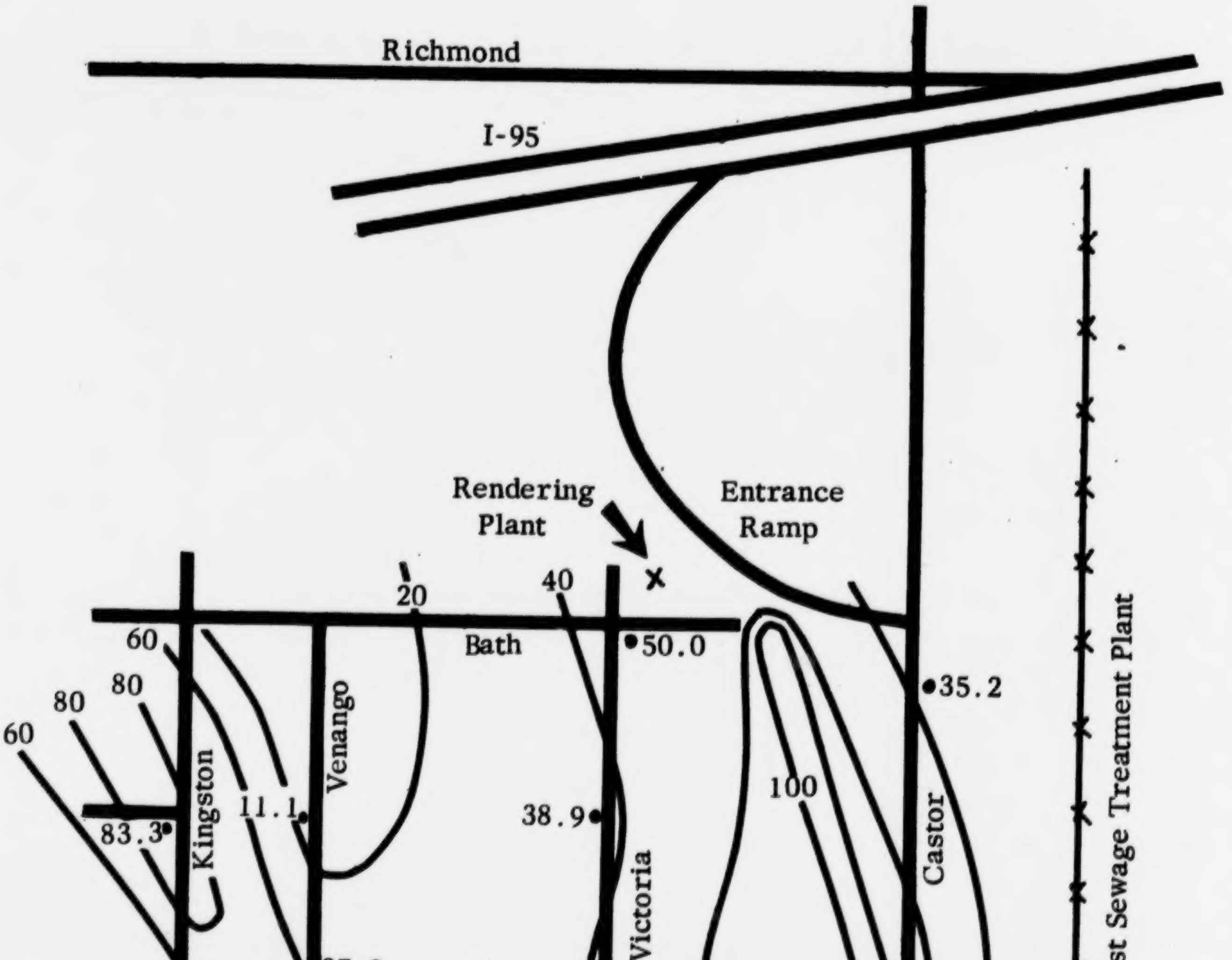
RENDERING FACILITIES ODOR EMISSION
DISPERSION PATTERN
(Contours based on mean odor intensities)


Richmond
I-95
Castor
Southeast Sewage Treatment Plant
Rendering Plant
Entrance Ramp
Bath
Kingston
Venango
Victoria
Balfour
0.50
0.40
1.00
0.38
0.39
0.23
1.15
0.36
2.00
0.50
2.33
0.59
1.53
0.46
1.00
0.50
0.28
N
0
500'

Source: Engineering-Science, Inc.

Figure 15

RENDERING FACILITIES ODOR EMISSION DISPERSION PATTERN
(Contours based on percent of time odor was perceived)


Richmond
I-95
Rendering Plant
Entrance Ramp
20
40
Bath
50.0
60
80
80
60
Kingston
Venango
11.1
83.3
Victoria
38.9
100
Castor
35.2
Southeast Sewage Treatment Plant
Balfour
37.0
48.1
42.6
96.3
80
70.4
24.1
N
0
500'

Source: Engineering-Science, Inc.

Notes

1. Amos Turk and Stanley Mehlman, "Correlations Between Instrumental and Sensory Characterization of Atmospheric Odors," *Correlation of Subjective-Objective Methods in the Study of Odors and Taste*, Special Technical Publication No. 440 (American Society for Testing and Materials, 1968), p. 29.

2. Norman A. Huey, *et al*., "Objective Odor Pollution Control Investigations," *Journal of the Air Pollution Control Association*, X, No. 6 (December, 1960), pp. 441-446.

3. *Ibid*., p. 442 and 443.

4. Turk, *op. cit*., pp. 31-33.

5. *Ibid*., pp. 32 and 33.

6. Amos Turk and Janet Wittes, "The Selection of Judges for Odor Discrimination Panels," *Correlation of Subjective-Objective Methods in the Study of Odors and Taste*, Special Technical Publication No. 440 (American Society for Testing and Materials, 1968).

7. *Ibid*., pp. 53-57.

8. *Ibid*., p. 52.

References

Turk, Amos and Mehlman, Stanley. "Correlations Between Instrumental and Sensory Characterization of Atmospheric Odors," Correlation of Subjective-Objective Methods in the Study of Odors and Taste. Special Technical Publication No. 440, American Society for Testing and Materials, 1968.

Huey, Norman A., et al. "Objective Odor Pollution Control Investigations," Journal of the Air Pollution Control Association, X, No. 6 (December, 1960), 441-446.

Turk, Amos and Wittes, Janet. "The Selection of Judges for Odor Discrimination Panels," Correlation of Subjective-Objective Methods in the Study of Odors and Taste. Special Technical Publication No. 440, American Society for Testing and Materials, 1968.

CHAPTER IX

PUBLIC OPINION SURVEY

The public opinion survey was conducted by Copley International Corporation as an exploratory approach to determine the degree to which odors constitute a significant influence on the lives of people living and working in actual odor problem areas.

Within this broad framework four objectives were established and research was designed to explore and/or develop data on each. These objectives were to determine:

(1) How aware people are of odors.

(2) If there are differences in opinions between people living in odor problem areas and people living in relatively odor-free areas.

(3) If people living in odor problem areas feel they have suffered, either socially or economically, due to odors.

(4) The degree of interest the public may have in solving odor problems.

Since no prior research has been conducted in the area of public opinions on odors, this survey was designed as a broad, exploratory approach toward establishing benchmarks from which more definitive research thrusts can be made. Essentially, it constitutes the basic research cornerstone necessary for a planned exploration into an area with many unknowns. As is the case in any research of an exploratory nature, the data generated should be used to develop hypotheses and direct further research into more effective channels. Therefore, the findings should not be considered as definitive or as requiring no further investigation.

Because of the exploratory nature of this study, a variety of questions and question approaches were used with the expectation that some would generate usable data while others might not allow for valid discrimination between the variables. The survey was conducted in the principal cities of seven metropolitan areas to obtain a representation of opinion from individuals in different regions of the United States as well as different stations in life.

This chapter provides a description of the development of the public opinion survey and a summary of the survey results. The findings are divided into three major sections:

(1) An analysis of the opinions of male and female adults in households (hereafter referred to as residents).

(2) An analysis of the opinions of businessmen.

(3) A comparison of results obtained from each of the cities surveyed.

DEVELOPMENT OF THE SURVEY

Description of Survey Technique

Within each city investigated, the team of engineers from Engineering-Science, Inc., in conjunction with officials of the local air pollution control agency in that city, selected one or more actual odor problem areas for investigation. The engineering team determined the boundaries of each of the odor problem areas, sketched the boundaries on a city map (see Appendix E), and conducted technical field studies within the described boundaries.

Upon completing their studies in each city, the team of engineers deposited the map at the office of the local air pollution control agency, for later retrieval by the CIC survey director, and then traveled to the next city scheduled for investigation. Within a day or two the survey director retrieved the map.

In preparation for selecting a sample of residents and businessmen to interview, the survey director then called upon the marketing research staff of the local newspaper to obtain information concerning the demographic composition of the odor problem areas described on the city map. (Most newspapers in large metropolitan areas maintain a wealth of recent demographic information on the potential audience in their market area.)

Utilizing the acquired information, survey test and control areas were established. The control area in each city was selected to match as nearly as possible the test area in terms of socio-economic characteristics, yet be as free as possible of odor problems. Appendix E presents detailed information on the area boundaries as well as an analysis of the socio-economic characteristics of the matched areas.

A single test area was established in four of the cities surveyed. In contrast, it was necessary to establish two test areas in the other three cities to provide adequate representation. With the exception of Tampa, all of the cities had a single control area. Table I indicates the number of test and control areas established in each city.

Table I

NUMBER OF TEST AND CONTROL AREAS IN EACH CITY

City	Number of Test Areas	Number of Control Areas
Portland, Oregon	1	1
Cincinnati, Ohio	2	1
Kansas City, Missouri	1	1
Buffalo, New York	1	1
Philadelphia, Pennsylvania	2	1
Tampa, Florida	2	2
San Francisco, California	1	1

Source: Copley International Corporation.

Prior to the sampling and interviewing conducted in each city, the survey director contacted a local interviewing service company to complete final preparations for the survey work. Printed questionnaires and interviewer instructions were sent to each company in advance to allow as much time as possible for staff familiarization. Meetings were held with the interviewing company supervisor in each city to discuss and complete details of sampling, briefing, execution, and verification of the survey design.

Sampling was conducted in the following manner. Within each test and control area, all blocks were numbered in a serpentine order. From each area, approximately 35 blocks were randomly selected in an "every-nth" fashion to provide geographic dispersion of the households drawn for the public opinion sampling of the residents.

Using a street address (reverse-order) telephone directory, all telephone numbers were listed for each block selected for the sample. Again, using the "every-nth" random selection procedure, five primary and two alternative phone numbers were selected for each block. Whenever a block did not have the required number of telephones listed, the remainder were selected from an adjacent block in the same random fashion.

Purposive sampling was used to select the retail businessmen from each area. Available business and professional establishments within each area were listed. From this listing 25 were judgmentally selected to provide a wide variety of retail outlets. It was planned to include types of retail outlets which could conceivably suffer loss of patronage because of odor pollution in the vicinity. Table II provides a list of the types of retail outlets which were considered for this sampling.

Table II

BUSINESS AND PROFESSIONAL ESTABLISHMENTS LISTED FOR SELECTION OF BUSINESSMEN RESPONDENTS

Appliance stores
Auto dealers
Bars, taverns, and nightclubs
Beauty and barber shops
Book and stationery stores
Camera and photographic shops
Clothing stores
Department stores
Drive-in eating places
Drive-in movies
Drug stores
Florist and garden shops
Food and grocery stores; supermarkets
Furniture stores
Hardware and building supplies stores
Jewelry stores
Laundry and dry cleaning shops
Liquor stores
Motels
Music and record stores
Pet shops
Physicians and dentists offices
Restaurants and cafes
Service stations (gas and oil)
Shoe stores
Sporting goods stores
Tire and auto accessory shops
Variety, novelty, and gift shops

Source: Copley International Corporation.

Only professionally trained interviewers were used. They were selected, briefed, and supervised by the local interviewing company supervisor who was assigned the responsibility for the execution of the survey.

All interviewers were briefed verbally and given two detailed sets of "Instructions to Interviewers," one set for use in interviewing residents of households, the other set to use with businessmen (see Appendix N). These instructions gave detailed advice on how the interviewer should proceed in selecting individual respondents and in administering the questionnaires.

The interviewing procedure required an initial call plus up to five follow-up calls, as necessary, to contact each respondent. Only after six unsuccessful attempts to contact a respondent was an alternate telephone number to be used. This callback technique provided for a high rate of completion of the sampling units originally selected, and thus generated a more representative sample than otherwise could have been obtained.

The interviews were scheduled to begin as soon as possible after the ESI engineering team had delineated the test areas. Table III indicates the dates during which the public opinion survey was conducted in each city.

Table III

DATES DURING WHICH PUBLIC OPINION SURVEY WAS CONDUCTED

City	Dates
Portland	September 24 - October 1, 1969
Cincinnati	October 3 - October 10, 1969
Kansas City	October 6 - October 10, 1969
Buffalo	October 14 - October 21, 1969
Philadelphia	October 20 - October 25, 1969
Tampa	October 20 - October 25, 1969
San Francisco	October 27 - November 1, 1969

Source: Copley International Corporation.

When two test or control areas were designated in a city, the sample was divided and approximately equal numbers of interviews were completed in each area. The survey design called for a total of 400 completed interviews in each city. Of this total, 200 were to be conducted in the test area and 200 in the control area.

In both the test and control areas, the sample was further divided. Of the 200 interviews to be conducted in an area, 175 were to be with residents (male and female adults in households) with an approximate 50-50 split between males and females, while 25 were to be with small retail businessmen. Table IV indicates the total number of interviews completed in each of the cities surveyed, while Table V provides the breakdown of the total number of interviews of residents completed, by men and women.

The survey technique employed in each city was identical. In compliance with the project budget and specifications, all interviews were made by telephone. The exception was in San Francisco, where the available supply of telephone numbers in both the test and control areas was exhausted and personal interviews had to be conducted to supply the required number of responses.

Table IV

TOTAL NUMBER OF INTERVIEWS COMPLETED IN EACH CITY

City	Test Residents	Test Businessmen	Control Residents	Control Businessmen
Portland	173	25	177	25
Cincinnati	175	25	175	25
Kansas City	175	25	175	25
Buffalo	175	25	175	25
Philadelphia	175	25	176	25
Tampa	175	25	175	25
San Francisco	177	25	160	25

Table V

TOTAL NUMBER OF INTERVIEWS OF RESIDENTS COMPLETED, BY MEN AND WOMEN, IN EACH CITY

City	Test Men	Test Women	Control Men	Control Women
Portland	72	101	61	116
Cincinnati	89	86	82	93
Kansas City	89	86	87	88
Buffalo	89	86	83	92
Philadelphia	90	85	86	90
Tampa	87	88	88	87
San Francisco	69	108	79	81

Source: Copley International Corporation.

Description of the Questionnaires

The questionnaires were designed to generate a variety of data which could be used in obtaining a measurement of opinions concerning the effects of odor problems. The opinions of householders were sought about the areas in which they lived and the opinions of businessmen about the areas where they operated retail businesses.

The CIC professional staff involved in this study provided many ideas and suggestions on the composition of the questionnaires to be administered to residents and businessmen. In addition, a number of questions included in a recent air quality opinion survey of Clarkston, Washington, were adapted for use.[1] After pretesting a preliminary form and incorporating the suggestions of the National Air Pollution Control Administration, the final forms of the questionnaires were developed.

The questionnaire constructed for administration to residents (see Appendix N) was designed to shed light on a number of objectives. Questions 1 through 6 were structured to determine the degree of satisfaction or dissatisfaction people had with the area in which they reside. These questions provided respondents the opportunity to volunteer any belief that odor problems existed in their neighborhoods.

Thus, one purpose of these six questions was to obtain an unaided recall measurement of odor problems. If respondents did not volunteer information concerning odor problems, the subject was then approached through subsequent questions which aided recall. The rationale was that greater confidence could be placed in awareness of odor problems when the respondent volunteered the information than if the subject had to be introduced through prompting. In addition, Question 3 attempted to obtain a measurement of how the respondents ranked some of the common social and economic problems in their areas relative to the general problems of air pollution.

Question 7 was designed to determine, through direct (aided) questioning, whether or not respondents were aware of air pollution in their area and, if so, in what time periods it was most noticeable. At this point, the interview was focused on air pollution; odor problems had not yet been mentioned by the interviewer.

Question 8 asked respondents to define the meaning of air pollution, thus allowing them an additional opportunity to volunteer an environmental association with odors. If odors were mentioned, respondents were then asked to describe what the odors smelled like.

Question 9 sought to determine if respondents were aware of odor problems in their area, even if the respondent had not mentioned such problems in the interview up to this point. If an awareness of odors was revealed, respondents were then asked if they knew the sources of these odors. Question 10 provided a slightly different approach to determining awareness of odor pollution by asking if the respondents felt the problem had been increasing, decreasing, or was constant.

Questions 11 through 15 were designed to be answered only by those individuals who indicated in Question 10 that they were aware of odor problems in their neighborhoods.

Questions 11 and 12 were structured so that respondents could indicate how they felt about the efforts of the local government to control odor pollution, and whether or not they felt more money should be spent in attacking the odor problem. These questions also provided for some measurement of the intensity of their feelings toward odor problems. Similarly, Question 13 attempted to note the degree of their feelings and reactions to odor problems by assuming those most troubled by odors would attempt greater efforts to reduce or eliminate the odors from their homes.

Questions 14 and 15 were designed to obtain a very rough measurement of whether or not the respondents felt odor pollution had harmed them economically or socially. Questions 16 and 17 were designed to develop additional data on the possible effects of odor pollution in areas removed from their immediate residences, i.e., where they worked or shopped.

Questions 18 through 28 were included to collect data to provide a comparison of the socio-economic characteristics of the respondents. These questions also enabled detailed analyses to be made by allowing for examination of economic and demographic factors as they relate to answers given to other questions.

The questionnaire form developed and directed to the businessmen (see Appendix N) was very similar to the form used with residents, with two exceptions. First, the businessmen were questioned concerning the relationship between odor problems (among other factors) and their business establishments rather than their residential areas. The other major difference was that economic and demographic data was not collected from businesses because of restrictions established by the Bureau of the Budget. As a consequence of this last difference, no relationships could be drawn between economic and demographic factors and data on the other variables gathered in the survey of businessmen.

Description of the Statistical Analysis Applied

In the following summary of findings, frequent reference is made to the tables in Appendices G through M. These tables present the survey findings. Responses were tabulated and a percentage distribution was prepared for each question. Findings for both the test and control areas, as well as total responses, are presented in these appendices.

The tables in the appendices are numbered in a fashion that permits easy reference to the original question in the questionnaire. For example, Table Q2A in Appendix G presents the findings of Question 2A on the "General Public" questionnaire.

Each table in Appendices G and L also contain significance test designations. Chi-square tests were conducted to determine if there were significant differences between the test and control areas.[2] In addition to the five percent levels, one percent significance levels were also used. Keys on Appendices G and L indicate the symbols used to signify: significant to the one percent level, significant to the five percent level, not significant at the five percent level, and chi-square tests not applicable.

SUMMARY OF RESULTS

Residents - Summary of All Cities

This summary is based on the results of all cities combined (Appendix G) and, as such, is representative of findings which might be obtained if identical studies were to be conducted in other comparable cities elsewhere in the nation.

The type of resident found in both the test and control areas in this study can perhaps best be characterized as lower-middle class. The resident tended to be a blue collar worker, middle-aged or older, below average in education and income, and with family size lower than average. An excellent division of the sample between men and women was obtained (approximately 47-53 percent). The occupational category of sales/white collar is sizeable because of the number of women clerical workers obtained in the sample. Men were typically employed as factory and service industry workers, truck drivers, or construction workers.

Most residents interviewed liked their test and control areas as a place to live (Q1). Approximately 60 percent of the respondents rated their area of the city as an excellent or good place to live. Only 10 percent rated it as poor or very poor. Residents of the control areas tended to rate their areas somewhat higher than did residents of test areas.

A sizeable proportion of the residents of both test and control areas, approximately 54 percent and 45 percent, respectively, could think of disadvantages about living in their particular area of the city (Q2A). It is significant to note that a larger proportion of test than control area residents could think of disadvantages.

When asked what some of these disadvantages were, approximately 16 percent of the test group and 2 percent of the control group mentioned air pollution (Q2B). About 6 percent of the test group and 2 percent of the control group also mentioned odors. These unaided responses indicate a highly significant difference between the two groups in terms of air quality perception.

Residents of both groups were also dissatisfied with: street disrepair, deteriorated areas, traffic, and dirt/litter. To a lesser degree, they were dissatisfied with: transportation, crime, noise, and undesirable people.

Residents of both groups were also asked to rate their areas of the city on a number of community problems. Air pollution was considered the most severe problem in the test areas, followed closely by high taxes (Q3, "Serious" and "Somewhat Serious" responses combined). The residents of the control areas did not view air pollution as being as severe a problem (see Table VI).

Table VI

PERCENT OF RESIDENTS INDICATING THE FOLLOWING COMMUNITY PROBLEMS WERE SERIOUS OR SOMEWHAT SERIOUS IN THEIR TEST AND CONTROL AREAS

Community Problem	Test	Control
Air pollution	65%	36%
High taxes	62	89
Deterioration of streets, parks, etc.	42	34
Crime	38	33
Water pollution	33	22
Inadequate public transportation	30	32
Deterioration of homes, stores, etc.	28	23
Racial tensions	18	11

Source: Copley International Corporation.

With regard to taking action and complaining to a local agency about some problem in their areas of the city, about 22 percent of the test area residents had done so compared to 18 percent for the control area (Q4A). When asked what the problems were about which they had complained, 10 percent of the test area complainants indicated air pollution compared to only 2 percent of the control area complainants (Q4B). Air pollution was the only problem mentioned that showed such a marked distinction between the two groups. This provided an additional indication of the similarity of the test and control areas in all variables except the degree of air and odor pollution.

Other problems ranking high as the subject of complaints were: juvenile delinquency and vandalism; street disrepair; mosquitoes, rats, and snakes; heavy, noisy, and speeding traffic; poor utility service; derelict buildings; theft; and sewers. In response to this last item, poor sewerage was cited as the main problem. However, the attendant odors may have been a major factor in prompting the demands for action.

Many of the people who made complaints had little knowledge of where to address them. For example, many complaints about air pollution were made to the police or to city hall rather than to the local air pollution control agency or health department. This is not readily apparent from looking at the summary data (Q4C) but is revealed when individual questionnaires are studied.

Residential mobility was low for both areas (Q5). The residents of the test areas appeared to be slightly more stable in terms of long-time residence than people in the control areas. However, roughly 30 percent of each group had thought seriously about moving to another area (Q6A). Table VII presents some of the major reasons given by respondents for desiring to move from their areas (Q6B).

Table VII.

PERCENT OF RESIDENTS INDICATING THE FOLLOWING MAJOR REASONS FOR DESIRING TO MOVE FROM THEIR TEST AND CONTROL AREAS

Reasons for Desiring to Move	Test	Control
Get bigger and/or better house	18%	17%
Move into suburbs	16	11
This area deteriorated	14	17
Personal reasons	14	15
Pollution	8	1
Better school district	7	4
Newer and cleaner area	6	11
Get smaller house or apartment	5	7

Source: Copley International Corporation.

While the proportion of people in the test areas who mentioned pollution is not high (about 8 percent), it is significant that only one percent of the control group cited this reason. The significance of this difference is enhanced by the fact that these responses were not aided or prompted, but were completely voluntary.

When residents were asked specifically if there was air pollution in their areas of the city at any time during the year, approximately 70 percent of respondents in the test areas replied affirmatively. Only 36 percent in the control areas responded in this way (Q7A).

Residents who stated they did have air pollution in their areas were asked when they noticed it the most (Q7B). Summer drew the largest number of responses from both test and control areas. Many of these respondents commented that this was the season of year when they spent more time outside the house and thus were more apt to notice air pollution.

In both test and control areas a sizeable proportion of responses mentioned the occurrence of air pollution during the morning or during the day. This time period was of greater concern in the control areas than in test areas, however. By contrast, mention of air pollution occurring in the evening, or when it was dark, was of major concern in test areas but not in control areas. Approximately 19 percent of the test group mentioned this time period compared to only 9 percent of the control group. In the test areas, respondents remarked to the effect that factories waited until it was dark so that people would not see the pollution pouring from their smokestacks.

Further questioning was conducted to determine what the term "air pollution" meant to the respondents (Q8A-Q8E). Of the five conditions examined only two elicited a significant difference between the test and control groups, with higher proportions of the test groups stating that they considered odors, and haze or fog, as part of what they meant by air pollution. Table VIII indicates the proportion of respondents in the test and control groups who felt the indicated conditions meant air pollution to them.

However, within the test area, two conditions mentioned most were smoke or dust and noticeable odors. Smoke or dust was the only similarly high-ranked condition in the control groups. Thus, in odor problem areas, odors are as highly equated with "air pollution" as are other conditions.

Table VIII

PERCENT OF TEST AND CONTROL AREA RESIDENTS INDICATING THE FOLLOWING CONDITIONS WERE ASSOCIATED WITH AIR POLLUTION

Condition	Test	Control
Smoke or dust	84%	82%
Noticeable odors	82	66
Irritation of the eyes	69	66
Nose or throat irritation	65	66
Haze or fog	58	50

Source: Copley International Corporation.

Residents who said that odor was associated with air pollution were then asked what some of these odors smelled like (Q8F). Two particular responses are notably different for the test and control groups. "Chemical" was highest for the test group, and "auto exhaust" was highest for the control group. Table IX summarizes the items most frequently mentioned by residents. Note the relatively high percentage of test area residents identifying odors smelled as "rotten." This is interpreted as more of a catchall of undefined replies than a specific category of smell.

When residents who had described one or more odors were asked which one they smelled most often in their area of the city (Q8G), the same major items were singled out as were mentioned in response to Question 8F and shown in Table IX. Table X summarizes those items most frequently mentioned by the residents.

Table IX

PERCENT OF RESIDENTS IDENTIFYING ODORS SMELLED IN THEIR TEST AND CONTROL AREAS

Odors Smelled	Test	Control
Chemical	19%	14%
Rotten	13	4
Eggs/Sulphur	13	11
Sewage	12	10
Oil/Petroleum	11	12
Burning	8	12
Burning hides/flesh	5	*
Trash/Garbage	4	8
Auto exhaust	3	16

* Less than 0.5 percent

Source: Copley International Corporation.

Table X

PERCENT OF RESIDENTS DESCRIBING ONE ODOR SMELLED MOST OFTEN IN THEIR TEST AND CONTROL AREAS

Odor Smelled	Test	Control
Rotten	13%	2%
Chemical	12	7
Eggs/Sulphur	8	5
Sewage	7	6
Oil/Petroleum	7	5
Burning	6	9
Burning hides/flesh	6	1
Auto exhaust	3	13
Garbage/Trash	2	6

Source: Copley International Corporation.

To investigate another dimension of the involvement of residents with odor pollution, they were asked directly how much odor pollution in their area of the city bothered them (Q9A). Again, distinct differences between test and control areas were obtained. Approximately 20 percent of the test area residents said "very much" compared to about 4 percent for the control area. And, 46 percent of the test area residents said "some" compared to only 30 percent for the control area.

Residents who stated that odor pollution in their area of the city bothered them "very much" or "some" were asked to identify the source or cause of the odors (Q9B). Many of the responses were vague. Even when residents were quite specific as to the type of source, very few could name specific companies as the odor originators.

Table XI shows some of the more frequently mentioned sources. Again, there are marked differences between the test and control areas. Almost 30 percent of the control area respondents viewed "traffic" as the dominant odor pollution source compared to only 7 percent in the test group. On the other hand, the test group focused on the more traditional odor pollution sources.

Table XI

PERCENT OF RESIDENTS INDICATING THEY WERE BOTHERED BY ODOR POLLUTION — BY ODOR SOURCE(S) IDENTIFIED

Odor Source	Test	Control
Chemical plant	28%	4%
Packing house	20	1
Factories	13	10
Steel plant	13	*
Oil refinery	9	2
Traffic	7	30
Swamp/River/Bay	6	3
Dump/Incinerator	5	13
Sewage	4	7

* Less than 0.5 percent

Source: Copley International Corporation.

Viewed against the dimension of time, residents in the test area again indicated their awareness of odor problems (Q10). About 20 percent of test area residents felt odor pollution was "continuously serious" compared with less than 5 percent in the control areas. Also, roughly 22 percent of the test area residents and 20 percent of the control area residents felt odor pollution was "becoming more serious." On the other hand, about 60 percent of the control area residents stated odor pollution was "not serious" in their area of the city, while only 26 percent in the test areas took this position. These individuals were not asked Questions 11 through 15.

In terms of the efforts that are being made to control odor pollution in their area of the city, 50 percent of the test area residents and 40 percent of the control area residents felt "some" or a "great deal of effort to control" odor pollution was being made. However, 36 percent of the test area and 40 percent of the control area residents felt "very little" or "no effort to control" odor pollution was being made (Q11).

Responding to another question directed at odor pollution control efforts, approximately 74 percent of the test area and 59 percent of the control area residents felt more money should be spent to control odor pollution in their areas of the city (Q12). However, in all cities in which this survey work was conducted, voluntary asides stressed the fact the money should come from the offenders and not from the taxpayers.

When asked what they do to reduce or eliminate offensive odors from outside sources that invade the home, over one-third replied "nothing" or "there's nothing you can do." Many residents felt there were few courses of action available and seemed resigned to living with the odors. About 25 percent mentioned closing doors and windows, and almost another one-third mentioned spraying or deodorizing (Q13).

An attempt was made to determine if residents experienced economic effects attributable to odor pollution. Residents were asked if they owned or were purchasing their home (apartment or townhouse). About 75 percent of the test area and 69 percent of the control area residents were classified as owners (Q14A). Those who owned homes were then asked if they felt odor pollution had reduced the value of their home property in any way. About 21 percent of the test area and 9 percent of the control area residents felt odor pollution had reduced the value of their property (Q14B).

When asked to relate how odor pollution had reduced their property values, almost half of the test area residents and over a third of the control area residents said potential buyers would change their minds if they came on a day when offensive odors were present. About 17 percent of the residents of both test and control groups showed some degree of confusion between air pollution and odor pollution by answering that the odor pollution ruined the paint and/or left a film on their houses (Q14C).

At this point a comparison question — "Have you ever seriously considered moving away from here because of odor pollution in the air?" — was asked so that the response might be compared with the unaided answers received from Question 6. With prompting, about 17 percent of the test area and 11 percent of the control area residents agreed that they had (Q15).

As noted previously in Table VII, 8 percent of the test and one percent of the control area residents volunteered they had thought seriously about moving because of pollution (Q6B).

A very small proportion — around 2 percent — of both groups indicated there were stores or shopping areas in the city which they did not patronize because of odor pollution (Q16A).

About half of the respondents were employed away from home. Of these employed residents, almost a third reported odor pollution bothered them "some" or "very much" at the place where they worked (Q17A). The majority of these reported it merely "smelled bad" but roughly 10 percent each reported eye irritation, a choking feeling, and dirt/dust problems. Responses were very similar between test and control group workers (Q17B).

In summary, many of the people living in the areas affected by odor problems are very much aware of these problems. They are also aware of the offending source(s). They seem to be disturbed and want something done about it. However, many of them appear to have a feeling of hopelessness, believing they have little power to change the situation.

Many residents see the abatement problem as belonging to the industries that create the odors. Respondents felt that those producing the odors should pay to eradicate them.

There is a high degree of agreement among residents of the particular areas with regard to the factors that constitute air pollution. The people, especially in polluted areas, put great emphasis upon odors as integral elements of air pollution.

Residents - Summary of All Cities by Demographic Breakdown

Cross tabulations by income, education, occupation, and age were developed for Questions 1, 3, 8, 14 and 15 for both the test and control groups. Appendix H contains these tables for income, Appendix I for occupation, Appendix J for education, and Appendix K for age.

A complete individual summary of every table in these appendices is beyond the scope of this report due to the magnitude of the data. In addition, many of the tables fail to reveal any especially meaningful information. Therefore, significant highlights have been chosen and summarized briefly.

Overall, control area residents were more satisfied with their area of the city as a place to live than were test area residents. In both groups, highest ratings were given by those individuals reporting incomes in the upper ranges. The professional, technical, and managerial occupational types were decidedly more satisfied with their area than were the blue collar workers. Higher levels of educational attainment also seemed to be related to a better outlook on their area of the city. Residents below 24 years of age appeared more dissatisfied than did the other age groups.

The better educated, upper income, and older residents tended to view crime in their area of the city as being not quite as serious as did the younger, lower income, and least educated residents. The test areas were viewed as more serious than the control areas among those who admitted some degree of seriousness in the crime problem. This was especially true of those residents with incomes over $10,000 and holding white collar jobs.

Awareness of the water pollution problem in the respondents' area of the city was only slightly heightened by increased educational attainment, income, occupational level, and youth. By contrast, awareness of the air pollution problem in their area of the city rose markedly with increases in these same characteristics.

Deterioration of streets, parks, sewerage, utilities, public buildings, and so on, in their area was seen as more serious than pollution by the younger residents in the lower income groups who hold blue collar jobs. These same residents also viewed deterioration of shopping centers, stores, homes, and industrial buildings as being more serious than pollution.

Older residents viewed racial tensions as a more serious problem than pollution in their area of the city. Little difference resulted from variations in education, income, or occupation.

High taxes in their area of the city was viewed as decidedly more serious by the residents with lower incomes (including the retired and unemployed), lower educational achievements, and lower occupational categories.

Among the residents in both the test and control areas who felt their area of the city suffered from air pollution, no demographic differences were found relating to smoke or dust and haze or fog. However, irritation of the eyes, nose, and throat are considered important elements of air pollution by residents with better educations and higher incomes. A vast majority of all residents consider noticeable odors as a basic element of air pollution, with a slightly greater percentage of younger residents holding this view.

As might be expected, ownership of homes tended to rise with age, better educations, higher incomes, and white collar occupations. However, the younger residents in the test areas tended to feel more strongly that odor pollution had reduced the value of their property.

Age appeared to be the only demographic variable having an effect on a serious consideration to move from the area because of odor pollution. Younger residents gave greater consideration to moving.

Businessmen - Summary of All Cities

This summary is based on the findings reported in greater detail in Appendix L. It is a report of all seven cities combined and, as such, is representative of findings which might be obtained were identical studies conducted in other comparable cities across the nation.

The primary target of this portion of the overall survey was the small businessman who might suffer economic loss because of odor pollution in the area of his business. Most respondents were owners/managers. Their establishments were generally small. In terms of total number of people working in the establishment, including the owner/manager, the modal group was three. Approximately twice as many automotive establishments were sampled in the test areas as in the control areas. However, other types of businesses were well distributed between test and control areas (Q16B).

In general, most businessmen in both the test and control areas liked their area of the city for business. Approximately 65 percent of both test and control groups felt their area was "excellent" or "good" for business (Q1). Only 6 percent felt it was "poor" or "very poor."

However, 40 percent of the test group and 36 percent of the control group said they could think of disadvantages related to the area (Q2A). Of those mentioning disadvantages, theft was mentioned by 22 percent of the test group and 12 percent of the control group. The other two outstanding items indicating a marked difference between the two groups were parking, with 13 percent in the test and 22 percent in control group, and traffic, with 9 percent in the test and 17 percent in the control group (Q2B). Identification of traffic problems in control areas was principally focused on one-way streets. Odors were mentioned by 7 percent of the test and 3 percent of the control groups, roughly equivalent to the unaided response given by residents to the same question.

Crime in their area of the city was viewed with some degree of seriousness by approximately half of both test and control groups (Q3A). Businessmen, on the whole, tended to view the problem of crime as being a little more serious than did the residents (see Table XII).

Businessmen considered air pollution to be as serious as did residents. The same was true for the deterioration of streets, parks, sewerage, utilities, and public buildings (Q3C and Q3D). When the problem was identified as deterioration of stores, shopping centers, homes, and industrial buildings, both test and control area businessmen felt the problem was more serious than did the residents (Q3E).

On two particular problems businessmen in control areas appeared more concerned than businessmen in test areas (Q3G and Q3H). Approximately 51 percent of control area businessmen felt some degree of concern about high insurance premiums, compared to only 44 percent of test area businessmen. About 48 percent of control area businessmen were concerned about inadequate parking facilities, compared to 41 percent of test area businessmen.

Table XI

PERCENT OF BUSINESSMEN INDICATING THE FOLLOWING COMMUNITY PROBLEMS WERE SERIOUS OR SOMEWHAT SERIOUS IN THEIR TEST AND CONTROL AREAS

Community Problem	Test	Control
Air pollution	60%	34%
Crime	49	47
High insurance premiums	44	51
Deterioration of streets, parks, etc.	42	33
Inadequate parking facilities	41	48
Deterioration of shopping centers, homes, etc.	36	32
Inadequate public transportation	25	26
Water pollution	25	22
Racial tensions	17	17

Source: Copley International Corporation.

Businessmen were more active than residents in requesting some authority or agency to take action concerning some problem in their area of the city (Q4A). In addition, test area businessmen were more active than control area businessmen.

Theft was the primary complaint of about 25 percent of all businessmen while being mentioned by only 5 percent of all residents (Q4B). Test area businessmen were more concerned about vandalism and derelict buildings while control area businessmen complained about parking and street repair. Also, control area businessmen tended to complain more to the police while test area businessmen favored city hall by a wide margin (Q4C).

With both the test and control groups, the average businessman has operated his business in his area of the city for about ten years (Q5). Approximately 25 percent of test area and 20 percent of control area businessmen have thought seriously about moving to another area (Q6A). These percentages for businessmen are lower than responses given by residents of both test and control areas, perhaps reflecting the difficulty of relocating established business operations.

Reasons why businessmen would want to relocate could be expected to be different from those of the private citizen, at least in most respects. However, no mentions were made of air pollution by test area businessmen while 8 percent of test area residents had mentioned it. Some interesting differences were also discovered between test and control area businessmen (Q6B). Table XIII summarizes some of these differences.

Table XIII

PERCENT OF TEST AND CONTROL AREA BUSINESSMEN INDICATING THE FOLLOWING REASONS FOR WANTING TO RELOCATE THEIR BUSINESSES

Reasons for Wanting to Relocate	Test	Control
Area deteriorating	26%	34%
Crime	20	3
No money here/Move to wealthier area	14	19
Need to enlarge	11	3
Personal	9	9
No market here for product/service	6	19

Source: Copley International Corporation.

Two-thirds of the test area businessmen, compared to 26 percent of the control area businessmen, said there was air pollution in their area of the city at some time during the year (Q7A). While in test areas there was no significant difference in the level of response to this question between businessmen and residents, in control areas more residents than businessmen reported air pollution.

Businessmen who stated there was air pollution tended to notice it more during the day, and especially in the morning, than during the evening. Approximately 21 percent of the control area businessmen mentioned "summer" while 30 percent of the test area businessmen said "most of the time." (Q7B)

When asked what the words "air pollution" meant to them, "noticeable odors" was the only element which elicited a significant difference between the test and control groups of businessmen, with more test area businessmen mentioning odors (Q8). Table XIV summarizes the responses to the five conditions tested.

Table XIV

PERCENT OF TEST AND CONTROL AREA BUSINESSMEN INDICATING THE FOLLOWING CONDITIONS WERE ASSOCIATED WITH AIR POLLUTION

Condition	Test	Control
Smoke or dust	89%	93%
Noticeable odors	87	72
Nose or throat irritation	73	69
Irritation of the eyes	69	70
Haze or fog	47	47

Source: Copley International Corporation.

In describing the smell of some of the odors, test area businessmen stressed chemical, sewage, rotten flesh, and garbage smells while control area businessmen stressed exhaust and burning smells (Q8F). These responses were quite similar in proportion to those given by residents, with the exception that control area businessmen stressed "exhaust" much more than did control area residents.

Approximately 10 percent of the test area and 2 percent of the control area businessmen felt odor pollution had some effect upon their businesses (Q9A). This may be compared with 66 percent of test area and 34 percent of control area residents who indicated odor pollution bothered them to some degree. Apparently, odor pollution is not felt to be as demanding a problem in the business community as it is in the nearby residential neighborhood.

A further indication of this fact is the test area finding that 37 percent of businessmen and only 26 percent of residents felt that odor pollution in their area of the city was "not serious." However, 21 percent of the test area businessmen said it was "continuously serious" and 20 percent said it was "becoming more serious."(Q10)

Roughly half of both test and control area businessmen felt some degree of effort was being made to control odor pollution in their area, while about one-third of both groups felt little or no effort was being made (Q11). Also, 68 percent of test area and 58 percent of control area businessmen felt more money should be spent to control odor pollution in their area (Q12). As with residents, businessmen felt the offenders should be required to provide funds for control.

When offensive odors from outside sources invade their business establishments, 53 percent of test and 31 percent of control area businessmen said there was nothing they could do to reduce or eliminate them (Q13), while 21 percent of the test and 35 percent of the control area businessmen said there was no problem. However, approximately 35 percent of test and 44 percent of control area businessmen mentioned such actions as: closing doors, spraying, opening doors, air conditioning, and ventilating.

Approximately 9 percent of test and 2 percent of control area businessmen felt odor pollution had had a bad effect upon their business operation (Q14A). Only 6 percent of the test area businessmen, and none of the control area businessmen, said they had seriously considered moving their businesses from the area because of odor pollution (Q15).

Residents - Summary of Individual Cities

A detailed city-by-city analysis of the responses by residents to survey questions is presented in Appendix M. While the sample size in any one city was adequate for analyzing the total sample base for that city, caution should be used when interpreting the findings based on sub-samples. In some cases, the sub-sample sizes were too small to allow definitive conclusions to be drawn.

The summary of aggregate results from all cities has already covered the typical responses received in the survey. Therefore, this discussion will focus primarily on the exceptional findings for individual cities.

In San Francisco over 30 percent of both test and control area residents rated their area as "poor" or "very poor." The city that was judged most favorably by its residents was Cincinnati. Nearly 74 percent of Cincinnati control area residents rated their area of the city as "excellent" as did 35 percent of test area residents (Q1).

When asked if there were disadvantages to living in their area of the city, respondents in San Francisco were the most dissatisfied. More than four-fifths of test area and two-thirds of control area residents in San Francisco complained of disadvantages (Q2). Both areas are ghettos. More of the Portland test area residents complained of odors than in any other city or group. Nearly 27 percent expressed this complaint without aided recall (Q2B).

In San Francisco relatively large proportions of both test and control area residents rated crime, racial tensions, and high taxes as serious problems. In the Buffalo test area, 69 percent of the residents felt that air pollution was a serious problem, and almost 44 percent rated water pollution the same (Q3).

In Kansas City, Philadelphia, and San Francisco more control area residents had thought seriously about moving than had test area residents. Slightly more than half of the San Francisco control area residents had contemplated moving compared with almost 46 percent of the test area residents (Q6A).

For all cities except Portland, there was a significant difference between test and control area responses with regard to the presence of air pollution. In most cities the percentage of respondents citing air pollution ranged from nearly 30 to 50 percent greater in test areas. In Portland the difference was only about 11 percent. This may be attributed to the fact that both Portland areas are at times affected by air and odor pollution from a paper mill at Camas, Washington. Other than this, however, the control area is largely free of local industrial air pollutants (Q7).

In describing the nature of odors present in test areas, the largest proportion of Portland and San Francisco residents mentioned smelling "rotten" odors most often. "Burning hides/flesh" was mentioned by only slightly fewer Portland test area residents. Odors described as "chemical" were identified by a significant proportion of Cincinnati test area respondents, while "oil/petroleum" was mentioned most frequently by Philadelphia test area residents. A sizeable number of test area respondents in both Philadelphia and Kansas City were unable to describe the odors perceived most often or did not know which odors they were (Q8G).

Odor pollution bothered more test area residents in Philadelphia and San Francisco than in other cities. More than one-quarter of the respondents in both cities indicated that odor pollution bothered them "very much." (Q9A)

Summary of Survey Findings

In summary, a large proportion of the residents and businessmen surveyed were aware of the problem of air pollution. In defining air pollution, most of the respondents included "noticeable odors."

Residents in test areas identified air pollution as their area's most serious problem, followed closely by high taxes. In control areas the order was reversed. High taxes received the most mention, with air pollution a distant second.

Roughly half of all resident respondents could think of disadvantages associated with their areas, yet the population was not a very mobile one. About 79 percent had lived in the area six years or more. Approximately 30 percent indicated that they had seriously considered moving from the area, but only a small percentage because of air pollution.

Both residents and businessmen indicated that air pollution was most evident during the daytime and in the summer. However, unlike control area residents, a sizeable number of test area residents felt that air pollution was most noticeable during evening hours.

Odor, smoke, and dust conditions were those most usually associated with air pollution by both residents and businessmen. About 20 percent of test area residents felt odor pollution was a continuously serious problem, but only about 10 percent of the businessmen felt that business had been affected by it. Approximately 21 percent of the test area residents felt that property values in their area had been adversely affected by odor pollution.

Although awareness of air pollution problems tended to rise with increases in the residents' educational attainment, income, occupational level, and youth, survey area residents were very much aware of the problem. Young respondents were apt to consider noticeable odors as a basic element of air pollution to a slightly greater degree than did older residents. However, the vast majority of all age groups held this view. Most respondents also felt that more money should be spent on controlling odor pollution in their areas.

Notes

1. Nahum Z. Medalia, Community Perception of Air Quality: An Opinion Survey in Clarkston, Washington (Cincinnati, Ohio: U.S. Public Health Service, 1965).

2. For each question asked, the several response categories were cross tabulated against the test and control areas of all cities combined. If no difference between the two areas was found to exist, the percentage distributions should be identical. Since samples and not censuses were taken, a certain amount of difference between the two distributions was expected due to randomness. Therefore, a test of statistical significance was applied to determine whether the responses were independent of the area in which the question was asked.

   Formulated in this manner, the appropriate form of statistical analysis is that of contingency tables. Because the total number of interviews in the test and control areas was designed to be identical, both margin totals were not randomly determined. To simulate a randomness in the determination of both margins, the rejects, no-responses, and don't-know answers were eliminated. Thus, instead of comparing the distribution of all responses, only those that fitted into the remaining categories were compared.

   The determination of independence using contingency tables is accomplished by a chi-square (χ^2) test. The sample chi-square value for each table was calculated using the following expression:

$$\chi^2_{(r-1)(s-1)} = \sum_{i=1}^{r} \sum_{j=1}^{r} \frac{\left(n_{ij} - \frac{n_{i}.n._{j}}{n}\right)^2}{\frac{n_{i}.n._{j}}{n}}$$

   r = number of rows
   s = number of columns (always = 2 in this analysis)

The two distributions were said to be different if the observed sample chi-square value or a larger one had less than a 5 percent chance of occurring if indeed there was no difference. Put another way, if the two distributions were identical, then 95 percent of the time the calculated chi-square value should be between zero and some upper limit (determined from a table of chi-square values). If the observed chi-square value was above this limit, then it was concluded that there probably was a significant difference in the test and control area distributions.

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CHAPTER X

ASSESSMENT OF THE NATIONAL ODOR PROBLEM

The purpose of this chapter is to project the principal findings of this study to an assessment of the national odor problem. The initial section is concerned with the identification of potential odor problem areas throughout the United States. The application of the set of factors developed in Chapters II through V in locating these areas is described. The value of this method is discussed in terms of the correlation of data obtained from the survey of local air pollution control agencies.

Then, the results of the public opinion surveys in the seven metropolitan areas are projected to the nation as a whole. The final section presents a few observations concerning the legal recourse available as a solution to odor problems.

IDENTIFICATION OF POTENTIAL ODOR PROBLEM AREAS

Definition of Potential Odor Problem Areas

Potential odor problem areas may be defined as populated areas each having an odorant source (or sources) and an odorant supporting atmosphere. Odor problem potential may be expressed as a function of the population, odor producing potential, and atmospheric vulnerability of an area.

It is recalled that this study gave principal attention to the odor producing potential of industrial odorant sources. In fact, only industrial odorant sources are considered in the identification of odor problem areas by the method described in the following paragraphs.

A set of potential odor problem factors was developed not only to locate, but also to compare potential odor problem areas throughout the nation. The set of factors included:

(1) A quartile ranking of size of population in all three-digit zip code areas in the United States (Chapter V, Figure 1).

(2) A quartile ranking of the odor producing potential of industrial odorant sources in all three-digit zip code areas in the United States (Chapter V, Figure 2).

(3) A summary of the relative atmospheric vulnerability to serious odor problems of areas in the United States (Chapter V, Figure 3).

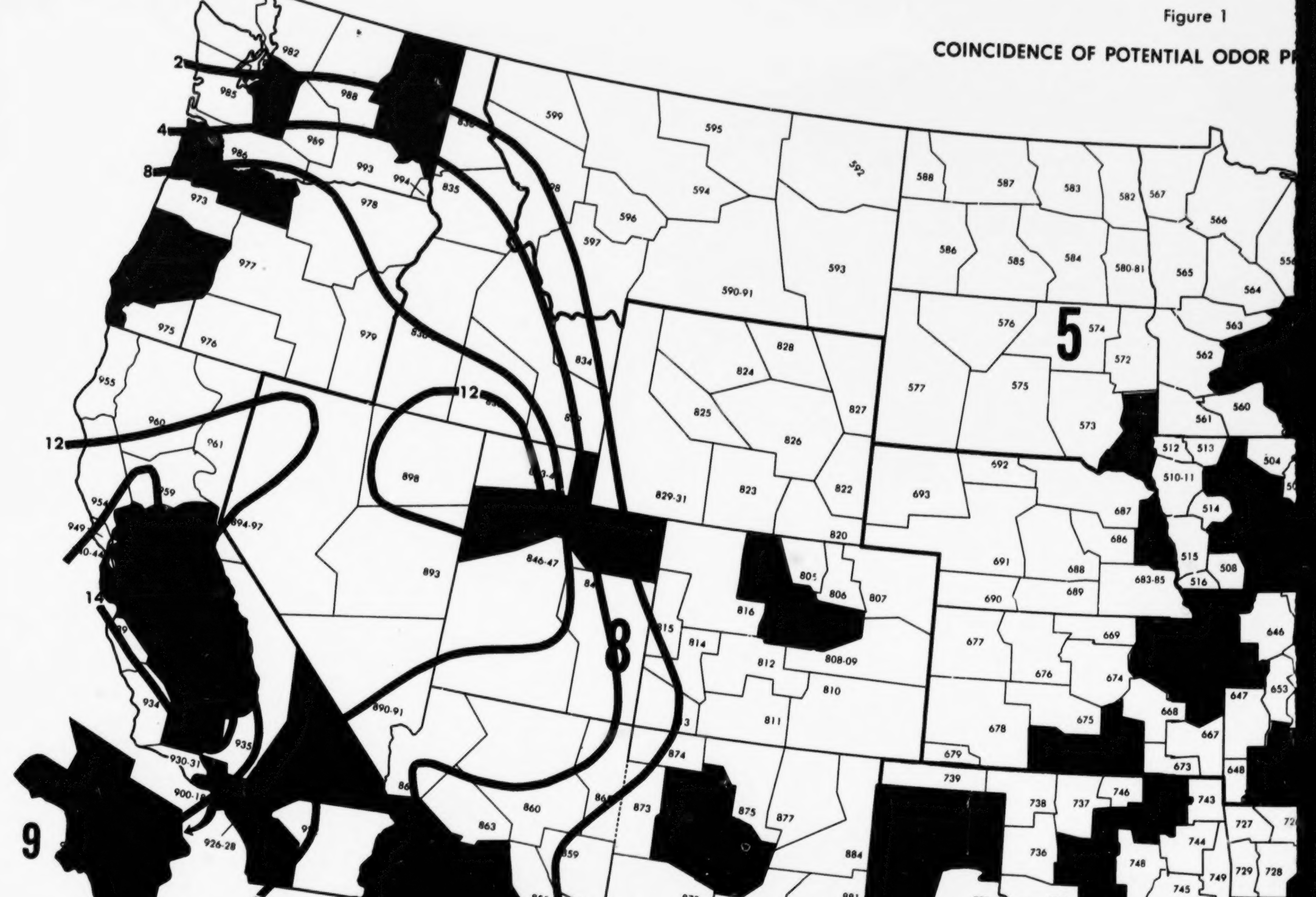
In applying these factors, one of sixteen possible combinations of the size of population and odor producing potential quartiles could be coincident in each three-digit zip code area. These combinations, along with the summary of atmospheric influence, are the parameters of problem potential. However, without a precise statement relating the three factors to an indication of overall influence, the relative problem potential of each area cannot be compared. The development of such a statement is beyond the scope of this study, however, a few generalizations can be made.

First, the least likely odor problem areas in the United States are among those having a coincidence of the lower quartiles of size of population and industrial odor producing potential and which are located within regions having the lowest frequency of air pollution warning periods. Second, within regions of equal atmospheric influence, areas having a coincidence of higher quartile rankings are more likely to be odor problem areas than areas having a coincidence of lower quartile rankings. Third, the most likely odor problem areas are among those having a coincidence of the upper quartile rankings and which are located within regions having the highest frequency of air pollution warning periods.

The relative odor potential of various zip code areas is shown on the following map. The purple-shaded areas within the higher numbered isopleths of Figure 1 (fold-out) represent the most likely odor problem areas in the United States. As indicated, they are found principally in the Appalachian and California Coastal areas. Because of occasional atmospheric vulnerability to serious odor problems in almost all areas of the United States, it is estimated that most of the purple-shaded areas of Figure 1 have experienced odor problems of a "serious" to "critical" degree.

Figure 1

COINCIDENCE OF POTENTIAL ODOR PR



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STATUTE MILES

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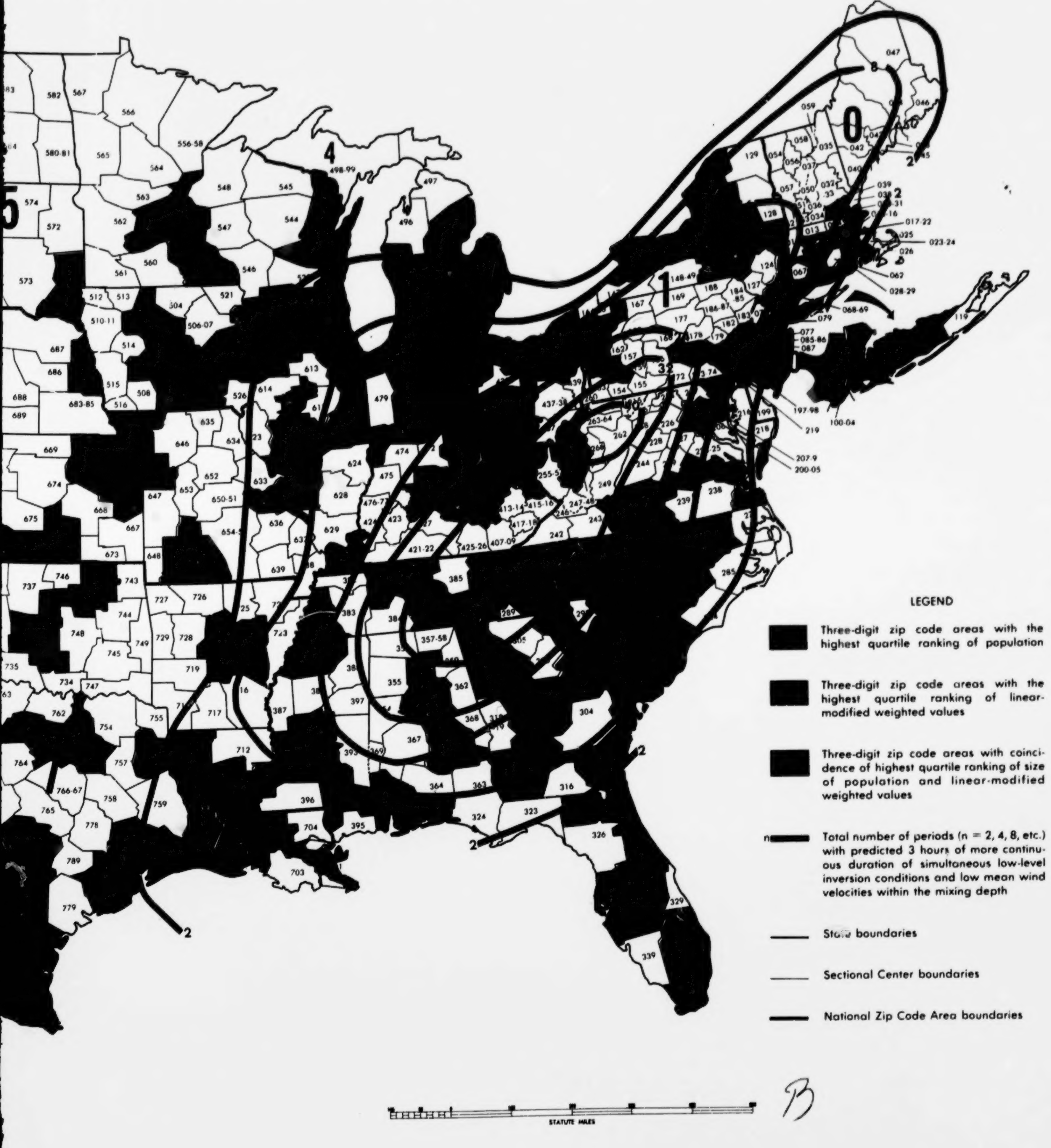
Figure 1

OF POTENTIAL ODOR PROBLEM FACTORS


LEGEND
■ Three-digit zip code areas with the highest quartile ranking of population
■ Three-digit zip code areas with the highest quartile ranking of linear-modified weighted values
■ Three-digit zip code areas with coincidence of highest quartile ranking of size of population and linear-modified weighted values
n Total number of periods (n = 2, 4, 8, etc.) with predicted 3 hours of more continuous duration of simultaneous low-level inversion conditions and low mean wind velocities within the mixing depth
State boundaries
Sectional Center boundaries
National Zip Code Area boundaries
STATUTE MILES
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B

Correlation of Potential and Actual Odor Problem Areas

If the assumptions incorporated in the development of the set of potential odor problem factors are valid, then the odor problem areas identified in this study should show positive correlation with actual odor problem areas as identified by local air pollution control agencies. To test this possibility, partial results of the survey of local air pollution control agencies were utilized. Specifically, the responses to Question 5B ("How many complaints about odors has your agency received in the past twelve months?") were compared to the three potential odor problem factors as follows:

(1) Because local air quality agencies typically serve individual cities or counties, it was necessary to combine the responses of certain agencies in an attempt to construct an equivalence to the areas of the three-digit zip code system. In only a few cases was this entirely successful.

(2) Despite this difficulty, the responses from 56 approximately equivalent three-digit zip code areas were ranked in order of highest to least number of complaints.

(3) Each odor problem factor was ranked in order of highest to lowest value for the same 56 three-digit zip code areas. On the assumption that the factors are of equal influence, an average rank was computed for each of the 56 three-digit areas.

(4) The number of complaint rankings representing actual odor problem areas and the average rankings representing the problem potential of the same areas were correlated using the Spearman rank correlation technique. The correlation coefficient was found to be positive (+0.50).

It is emphasized that the Spearman analysis was performed only as a gross indication of the value of the method of potential problem area identification described above. A more refined analysis of the value of each potential odor problem factor as a contributor to the location of potential odor problem areas must await knowledge of how these factors should be related to overall influence. This method is expected to be much more informative at the five-digit zip code (neighborhood) level than the three-digit (metropolitan area) level, since the use of five-digit area data will provide much more accuracy in the location of concentrations of population and industrial odorant sources. However, the availability of additional data (especially population data on a five-digit zip code basis) is required before potential odor problems can be identified in terms of neighborhoods.

Projection of Results to the Nation as a Whole

In developing the set of potential odor problem factors, principal attention was focused on metropolitan areas. Under the criteria outlined in Chapter VII, seven metropolitan areas were selected for investigation from among the most likely odor problem areas in the nation. Although the seven metropolitan areas were representative of many geographic and atmospheric regions, kinds of industrial odorant sources, and types of people in the United States, it is unknown whether the results of the investigations conducted in those areas are representative of all metropolitan areas. However, it is expected that the results are generally representative of most metropolitan areas, assuming that most metropolitan areas contain industries known to be potential sources of odorant emission.

In accordance with the objectives of the technical field program, the Engineering-Science, Inc., team of engineers confirmed the locations, areal extent, and odorant sources of actual odor problem areas identified by the local air pollution control agencies in the principal cities of each of the metropolitan areas. The results of the public opinion surveys conducted in these areas indicated that a large proportion of residents and businessmen were aware of noticeable odors. Awareness of odors was found not only in the survey test areas but also in the relatively odor-free control areas.

Difficulty arises in attempting to extrapolate the awareness level of perception to the problem level. There appears to be a very nebulous transition between an expression of awareness and an expression of problem. In this study, the differentiation between these levels was attempted through careful development of the public opinion survey questionnaires. It was planned that the responses to the questionnaires would provide the necessary data for an assessment of the extent of odor problems in the survey areas.

Although a further difficulty arises in attempting to project the extent of odor problems beyond the survey areas, assumptions were formulated to assist in overcoming this problem. Based on these assumptions, the survey findings were used to assess the extent of odor problems in the metropolitan areas of the United States.

The survey findings of all cities combined (Appendix G) show that 65 percent of test area residents stated, without prompting, that air pollution was a problem. Furthermore, 82 percent of these residents believed odors to be a major element of air pollution. From this, it may be assumed that about one-half of the test area residents would state that air pollution is a problem and odors are a major element. Similarly, about one-quarter of the control area residents would state that air pollution is a problem and odors are a major element.

There are an estimated 137 million persons in the 155 metropolitan areas of the nation. Assuming that two-thirds of these persons are male and female adults in households (residents), that only 10 percent live in actual odor problem areas (similar to the public opinion survey test areas), and that 90 percent live in relatively odor-free areas (similar to the survey control areas), then a projected 25 million residents in the United States could be expected to state that air pollution is a problem and that odors are a major element.

Based on these assumptions, further projections of the extent of odor problems can be made:

(1) About one and one-half million residents would voluntarily state that odors are a disadvantage to living in their areas of their cities.

(2) Almost five million residents would admit that odors bothered them very much.

(3) More than five and one-half million residents would state that odors are a continuously serious problem.

(4) About three million residents would feel that odor pollution has reduced the value of their home property.

(5) Almost five million residents would have seriously considered moving away from their areas because of odor pollution.

(6) Only one-half million residents would have requested some authority or agency to take action concerning air pollution. The number of residents that would have requested action concerning odor problems would be a small fraction of this.

Similar projections of the response of businessmen were not possible because of a lack of information concerning the number of small businesses in the 155 metropolitan areas.

On the basis of the projections given above, a large number of residents perceive odors as a problem. Yet only a small percentage of these residents are motivated to seek recourse. The reasons for this apparent apathy cannot be inferred from the public opinion survey findings. Instead, additional study of attitudes is required to develop meaningful conclusions. The remaining section presents a few observations concerning the legal recourse that is currently available, should such recourse be sought.

LEGAL RECOURSE TO ODOR PROBLEMS

The Foundation of Legal Recourse

Following the 1955 federal act which authorized the Department of Health, Education and Welfare to develop an air pollution control program, numerous state and local governments responded in kind by establishing the mechanisms by which research and control programs could be implemented to curb air quality degradation. In most states the ultimate agency-level authority is vested in the local counterpart to the Department of Health, Education and Welfare. On the urban level there is often a split in the responsibilities and authority consignments between the local public health and air pollution control boards.

The Clean Air Act of 1963 provided the first substantial federal grants to local air pollution agencies with funds awarded on a three-to-one basis. More important, however, from the standpoint of legislation, the Act has been instrumental in the unprecedented expansion of control programs on both a state and local level. Now with the increased structural impetus provided by the Air Quality Act of 1967, state and local legislative enactments will inevitably give recognition to the inter-dependency of cities, states, and entire geographic regions in air quality management.

It is worthy of note, however, that although states like California and New York forged ahead of federal timetables in setting air quality standards consistent with or exceeding established criteria for particulate matter and sulfur oxides, none have succeeded in establishing effective legislation to abate the emission of environmental odors.

Enforcement Practice

The enforcement of established laws, regulations, and policies designed to control the level of air pollutants generally rests with the designated air pollution control agency in each urban area. In instances involving odorant conditions the most frequently used legislation are local or state ordinances regarding "nuisance" situations. An excellent example of such a law — one which is more carefully worded than many, yet still retains the weaknesses found in all — is the California Health and Safety Code CH. 2.5, Article 10, Section 24360:

> "A person shall not discharge from any source whatsoever such quantities of air contaminants or other material which cause injury, detriment, nuisance, or annoyance to any considerable number of persons or to the public or which endangers the comfort, repose, health, or safety of any such persons or the public or which cause or have natural tendency to cause injury or damage to business or property."

The requirement of a "considerable number" of persons to constitute a nuisance or annoyance renders the approach of limited utility. This stipulation, though not present in all similar state and local laws, typifies, nonetheless, the difficulty in establishing an enforceable case when dealing with the diffuse problem of odor emissions. As indicated in Chapter VI, formal complaints about many problems are few and infrequent.

Unlike situations wherein property damage and/or personal health is in acknowledged jeopardy, strong public reaction to odorant conditions is generally non-existent. Notable exceptions to the general attitude were found in the cities of Portland and Tampa. In one city, major activist groups evolved out of an initial concern about an odor emission, while in the other, efforts are being exerted at this time around a major theme of clean air.

Enforcement efforts to reduce odor emissions generally await specific complaints. The attitude of enforcement officers regarding such complaints varied in each metropolitan area investigated. These different attitudes were also reflected in the speed and manner in which the complaints were handled. Those agencies which viewed the complaints as an inconvenience or harassment generally responded more slowly and with less apparent effort to effect a resolution to the problem. The more aggressive agencies tended toward greater promptness in response, odor source identification, and problem resolution via odor abatement. However, none of the agencies interviewed by Engineering-Science, Inc., could claim significant control of odorant conditions in their areas even though the sources were fairly well pinpointed and identifiable. All those interviewed agreed that their regulatory frameworks were too poorly defined to effect proper enforcement among already existing industries which were responsible for the emissions. As confirmed by the survey of local air pollution control agencies, present-day abatement activities are principally aimed at resolution through the voluntary cooperation of the sources involved.

Beyond more definitive enforcement criteria, agency officials have expressed hope in the efficacy of plan review power, which some have been accorded through recent legislation. This authority permits air quality agencies to review plans for new facilities and to stop issuance of construction permits if reasonable steps are not taken to insure adequately clean operations.

Judicial Precedence

Adjudication of cases involving air pollution emissions is still in the embryonic stage. In most instances, intolerable conditions are resolved through compromises and concessions at the hearing level (either formal or informal) of the air pollution control boards.

To the extent this study was able to determine, none of the metropolitan areas investigated had records of any substantial fine or other judicial penalty involving environmental odor levied against an air pollution violator.

The Enforcement Agency

Public reaction to odor problems usually takes the form of individual complaints. Although conservationist groups are ever-present (in varied strength, number, and sophistication), few such groups have concentrated on the problem of environmental odor emissions. Most enforcement agencies are responsive, nevertheless, to the individual complaints reported by local citizens. They are usually fully cognizant of the nature and location of the static odors in their community, but are somewhat frustrated by their inability to effect odor abatement in the majority of cases. The enforcement agencies' perception of problem magnitude becomes accentuated when they occasionally bear the brunt of newspaper criticism. Some have attempted to offset unfavorable publicity by educating special interest groups and the general public via public information programs and speaker bureaus. However, this has sometimes backfired by creating demands which they have been unable to fulfill.

Many of the officials interviewed expressed the wish that industry would cooperate more fully by doing a better job of countering public pressure for odor abatement. It was believed that public information and education by private industry emphasizing what they are doing to reduce air pollutant by-products would be immensely helpful.

To date, the tools and devices available to enforcement agencies to deal with odor problems have been virtually nil. Legislative enactments have been inadequate and measuring devices almost non-existent. Both the federal government and local air pollution agencies, however, recognize the need to acquire answers. This study is an indication of such concern.

CHAPTER XI

CONCLUSIONS AND RECOMMENDATIONS

The conclusions of this study are presented below. They are drawn from the analyses of the study data and the experiences of the study team. Consistent with these conclusions and the study tasks, recommendations for further research directed toward an assessment of the social and economic impact of odors are also presented.

CONCLUSIONS

Based on the assessment of the national odor problem, it is concluded that odor problem potential exists in most metropolitan areas in the United States. But, primarily because of meteorological factors, the probability of encountering odor problems is greatest in the Appalachian and California Coastal metropolitan areas. It is further concluded that a large number of residents — perhaps as many as 25 million — perceive odors as problems and desire some form of abatement.

The results of the mail survey and personal interviews of local air pollution control agencies indicated that when concentrations of air pollutants can be related to amounts of property damage and/or ill health, abatement criteria (e.g., minimum levels of emissions) can be established and enforced. However, in cases of air pollutants causing only odors, such relationships are generally non-existent. Consequently, odor abatement criteria, if any, are typically based on number of complaints and inadequately backed by nuisance laws.

In order to support more effective odor abatement, some indication of the social and economic impact of odors on individuals must be developed. Perhaps relationships between the presence of odors and a few social and economic indicators (e.g., differences in property values) could be estimated. However, only a study of the attitudes of individuals who may be affected by odors could provide an assessment of the overall social and economic impact.

The basis for this assertion lies in the conception that attitudes show evaluative personal reactions — basically, tolerance or intolerance — to a situation such as an odorified environment. Furthermore, it is the attitudes of individuals toward the presence of odors as being intolerable that is the key to defining the existence of odor problems.

It is recognized that there are difficulties associated with obtaining a social and economic assessment through an attitude survey. For example, great care must be taken in the development of the survey questionnaire, the selection of the representative sample of individuals, and the interpretation of results in order that the assessment could be admissible in judicial proceedings. However, a single procedure could be professionally prepared to reduce survey complexities to an easily applied set of instructions, which could be used by relatively inexperienced authorities in any community in the nation. Although other difficulties exist with regard to assessing the social and economic impact of odors, it is felt that they provide no permanent obstacle to success.

RECOMMENDATIONS

Taking into consideration the present state of knowledge, it is recommended in cases where air pollutants are found to cause adverse effects on property and/or health, as well as intolerable odors, that abatement should be directed to relieve the adverse effects on property and/or health. Hopefully, such abatement would result in eliminating the problem of odors as well. In cases where odors alone must be relieved, it is recommended that abatement should be supported with an assessment of the social and economic impact on the individuals that may be affected.

The following discussion provides an approach that could be used in developing a method of assessment. Because most odor problems are local in terms of the area affected, the approach is focused on a specific odor problem. The discussion is meant to suggest the content of a continuation (Phase II) of the present study.

Objective and Methodology

The principal objective of further study would be to develop an efficient and inexpensive method that would provide an adequate assessment of the social and economic impact of a specific odor problem on a typical community in the United States. In order to develop this methodology, a minimum of two odor-affected test areas and one control area would be established within residential sectors of a metropolitan area. The metropolitan area would be representative of many types of people and kinds of industrial odorant sources in the nation. It would be chosen within a region of average atmospheric vulnerability to serious odor problems.

Because of the availability of information obtained during this study, initial consideration would be given to the seven metropolitan areas investigated in Phase I. However, the choice would not be restricted to those areas.

One of the test areas would be located near an odorant emitting industrial plant that has been in operation for a year or more. To minimize the effect of odor adaptation by residents, the second test area would be located near an identical industrial plant that has recently begun operations. The two test areas would be as near to each other and as similar as possible in all characteristics except for term of operation of the plants. The control area, also with similar characteristics, would be established nearby but would not be affected by odorants from either of the plants. This arrangement would allow a valid comparison of attitudinal variables between the residents of each area.

Recorded panel discussions with residents of each of the test and control areas would be conducted to identify attitudinal variables that may be related to the problem level of odor perception. This would be a preliminary step toward the development of an effective public attitude survey questionnaire.

To determine how odors influence the attitudes of residents, a number of public attitude surveys would be conducted by telephone periodically during the investigation. (It is recommended that the period of investigation extend up to six months to account for seasonal influences.) Different sample sizes would be used to determine the smallest size permissible to obtain meaningful survey results. This would provide a guideline for minimizing survey time and expenses.

Technical field studies using field sensory techniques would be used to measure the intensity, duration, frequency, and temporal variation of odors throughout the test areas. The results of scentometer measurements would be compared to the results obtained by trained odor panel evaluations. Different sized odor panels (of, say, 8, 12 and 16 panelists) could be used at different times to determine the effect on the correlation of the two techniques as evidenced in Phase I. These studies would be conducted concurrently with the public attitude surveys so that the data obtained from both could be used to develop close approximations to existing relationships. Meteorological data relating to atmospheric stability and wind characteristics would also be gathered for the period of investigation.

Development of an Odor Problem Index

The results of the public surveys and technical field studies between each of the areas (test area A vs. control area; test area B vs. control area; test area A vs. test area B) would be examined for significant differences. Should significance be found, multivariate techniques (including factor analysis) would be used to relate the differences in attitudinal variables to the differences in odor presence (intensity, duration, etc.), atmospheric (wind speed and direction, etc.), and demographic (age, income, etc.) variables.

From the above, an odor problem index would be developed to represent an overall attitude differential between any given test and control area. In addition, a set of generalized charts would be developed to relate significant odor presence, atmospheric and demographic variables to the odor problem index. Finally, a procedure would be developed to provide step-by-step instructions for the establishment of an odor problem index for a specific odor problem. The instructions would include:

(1) Specification of the information required.
(2) Techniques for collecting and analyzing this information.
(3) Approximate costs of various phases of the assessment.

This method would provide as brief and inexpensive an investigation as possible to obtain an adequate assessment of the social and economic impact of a specific odor problem on a typical community in the United States.

ANNOTATED BIBLIOGRAPHY

A. IDENTIFICATION OF MAJOR ODORANTS AND ODORANT SOURCES

American Society for Testing and Materials. Symposium on Odor. Special Technical Publication No. 164. Philadelphia: American Society for Testing and Materials, 1954.

A collection of six papers on odor sources, measurement and control together with a discussion.

City of Philadelphia, Pennsylvania. Department of Public Health. Air Pollution from Diesel Powered Vehicles in Philadelphia, 1965.

A discussion of the major pollutants of diesel engines. Recommends citations for diesel powered vehicles emitting excessive odors. 11 pages.

__________. Air Pollution from Fuel Combustion Processes in Philadelphia, 1966.

An analysis of major categories of combustion processes in terms of air pollution problems. Recommendations are made regarding control measures.

__________. Air Pollution Problems from Refuse Disposal Operations in Philadelphia and the Delaware Valley, 1969.

A discussion of the causes of air pollution from refuse combustion and the measures which may be taken to reduce emission, including odor control at incinerators. Ten pages.

__________. Sources of Air pollution Emissions in Philadelphia, no date.

A graphical summary of sources of major pollutants; sulfur dioxide, nitrogen dioxide, hydrocarbons, and particulates.

Crouse, W. R. and Flynn, N. E. "Source Inventory IBM System for Particulate and Gaseous Pollutants," *Journal of the Air Pollution Control Association*, XVII, No. 8 (August, 1967), 508-511.

Describes the rationale and methodology for compiling an emissions inventory, and the use of a computer for data processing and information retrieval.

Fieldnap, A. C., *et al*. *Warning Agents for Fuel Gases*. U.S. Bureau of Mines, Monograph No. 4, 1931.

A reference of perceptible concentrations and characteristics of various substances in air.

Gould, Robert F. (ed.) *Flavor Chemistry*. Washington, D.C.: American Chemical Society Publications, 1966.

Presents a collection of 15 papers dealing with practical problems associated with the presentation and enhancement of tastes and odors in foods.

Kerka, William F. and Kaiser, Elmer R. "An Evaluation of Environmental Odors," *Journal of the Air Pollution Control Association*, VII, No. 4 (August, 1957).

A survey of most common sources of environmental odors, together with a brief outline of physiological response variables, methods of measurement, and odor control methods. Five pages.

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A single volume introduction to air pollution; its causes, effects, and methods of control.

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A compilation of papers dealing with odor sources, evaluation, and technical and legislative control.

Randolph, T. G. Human Ecology and Susceptibility to the Chemical Environment. Springfield, Illinois: Charles C. Thomas, 1962.

Includes a list of chemical contaminants that produce odors and their subsequent effects on health (case study). Also contained are some examples of questionnaires with emphasis on reactions of individuals to chemical odors.

Schumann, Charles E. Air Pollutant Emissions in Cincinnati. Cincinnati, Ohio: City of Cincinnati, Division of Air Pollution Control and Heating Inspection, 1968.

Compilation of emission data based largely on fuel consumption data and standard emission factors. No data on odors. 15 pages.

Stern, A. C. (ed.) Air Pollution. 3 vols. 2nd ed. New York: Academic Press, 1968.

The most comprehensive treatment of all phases of air pollution available. Sections of most interest relative to odor problems are Part III, Air Pollution Meteorology, and Part V, Air Quality and Meteorological Measurements.

Summer, W. Methods of Air Deodorization. Amsterdam: Elsevier, 1963.

A comprehensive introduction to odors, including theories of olfaction, properties of odorants, meteorology, and detailed discussions of each of the common methods of deodorization.

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A compilation of information on particulates in terms of sources and properties, and economic and health effects. One chapter is devoted to odors associated with atmospheric particulate matter. 105 pages.

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A compilation of information on sulfur oxides in terms of sources, properties, means of measurement, and effects. Includes discussion of human olfactory response to various concentrations. 178 pages.

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A summary of air quality data for 1966, arranged by pollutants. Includes summary plots and detailed tabulations. No odor data per se. 157 pages.

B. MEASUREMENT OF INDUSTRIAL ACTIVITY

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A major study dealing with the problem of industrial concentration, empirical and theoretical. Various measures and economic variables are discussed in terms of concentration and size.

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A cross-sectional study of twenty manufacturing industries. Study focused on the relation between "the condition of entry" of new firms into an industry and the workability of competition in that industry. Recommendations offered for the design of a more effective antitrust policy.

George, Edwin. "Four Comments on 'The Measurement of Industrial Concentration': III," *Review of Economics and Statistics*, XXXIV (May, 1952), 168-172.

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Kaysen, Carl and Turner, Donald F. *Antitrust Policy: An Economic and Legal Analysis*. Cambridge, Massachusetts: Harvard University Press, 1959.

An evaluation of the limits and defects of traditional antitrust policy and a carefully detailed projection of possible reforms. Surveys the relative importance of different kinds of market structure in the economy.

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This manual provides listings of certain industrial activities by Standard Industrial Classification codes and the equipment associated with the air pollution generated by those activities.

National Bureau of Economic Research. Business Concentration and Price Policy. Princeton, New Jersey: Princeton University Press, 1955.

Separate discussions by various authors on subjects pertaining to business size, monopoly power, vertical integration, conglomerates, price discrimination, effects of taxes on concentration, etc. Mainly empirical investigations.

C. ATMOSPHERIC FACTORS RELATED TO ODOR PROBLEMS

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The development of meteorological criteria for permitting the open burning of deciduous fruit and nut trees is described. Basic criterion is a minimum of 2,500 feet vertical mixing. 15 pages.

Bay Area Pollution Control District. Air Pollution and the San Francisco Bay Area, 1969.

A general discussion of air pollution. Provides information on different kinds of smogs, various effects of air pollution, and statistics on counties in and around San Francisco area. A meteorological and geographical explanation of smog in the Bay Area is presented. Bay Area Air Pollution Control District and its functions are described.

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A short introduction to air pollution meteorology with special emphasis on diffusion climatology. The effects of inversion and wind conditions and stack height on diffusion of airborne pollutants is discussed.

Fuller, W. J. Specifications for Data Acquisition System Air Monitoring. Portland, Oregon: Columbia-Willamette Air Pollution Authority, 1968.

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Corrosion rates of mild carbon steel plates over the metropolitan Jacksonville area in a 44-station network were found to provide a good description of 50 dispersion patterns from major sources. Three pages.

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An urban diffusion model is presented, based on assumed uniform distribution of pollutant sources, and vertical diffusion from line sources up to the top of the mixing layer. A computer is not required. Five pages.

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Panofsky, H. A. and Prasad, B. "The Effects of Meteorological Factors on Air Pollution in a Narrow Valley," *Journal of Applied Meteorology*, VI (June, 1967), 493-499.

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A thorough and detailed study of the climatology of Hillsborough County, especially as it relates to air pollution. 85 pages.

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A description of the results of a series of nighttime tracer experiments conducted during the autumn of 1966 in the industrialized valley of Johnstown, Pennsylvania. An urban heat island effect is observed which modifies classical drainage flow patterns.

Stern, A. C. (ed.) Air Pollution. 3 vols. 2nd ed. New York: Academic Press, 1968.

The most comprehensive treatment of all phases of air pollution available. Sections of most interest relative to odor problems are Part III, Air Pollution Meteorology, and Part V, Air Quality and Meteorological Measurements.

Summer, W. Methods of Air Deodorization. Amsterdam: Elsevier, 1963.

A comprehensive introduction to odors, including theories of olfaction, properties of odorants, meteorology, and detailed discussions of each of the common methods of deodorization.

Turner, D. Bruce. Workbook of Atmospheric Dispersion Estimates. U.S. Public Health Service, PHS Publ. No. 999-AP-26, 1967.

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D. DEMOGRAPHIC FACTORS RELATED TO ODOR PROBLEMS

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An introduction to various ways in which postal zip codes can be utilized in business activity, and some examples of the way they are now being utilized. Significance as well as some deficiencies of the system are discussed.

Breslow, L. Air Pollution: Effects Reported by California Residents. Berkeley, California: State of California, Department of Health, 1956.

Investigation of the social and psychological aspects of daily living. Characteristics of samples such as sex, age, education, occupation, family income, etc. Major findings: 45 percent of California's adult population are bothered by air pollution. Eye and nasal irritation most frequent. People with chronic respiratory conditions are more sensitive. Most serious and extensive complaints from Los Angeles County.

Commercial Atlas & Marketing Guide. 100th ed. New York: Rand McNally & Company, 1969.

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Crowe, M. Jay. "Toward a 'Definitional Model' of Public Perception of Air Pollution," Journal of the Air Pollution Control Association, XVIII (March, 1968), 154-158.

From a public attitudinal survey conducted in a city in southwest Pennsylvania, different levels or aspects of public perception of air pollution are suggested. This model is analyzed in terms of selected social characteristics, such as education, socio-economic status, and residence.

Hillsborough County, Florida. Department of Health. Division of Environmental Engineering. Urbanization and Air Pollution, 1969.

Discusses the relationships which exist between increases in population and economic growth and environmental pollution. Vehicle emission controls are explained. Eight pages.

Jones, Richard W. "New Developments in Zip Code Marketing," *The Marketing Magazine* (June, 1969), A1-A6.

An introduction to the origin of postal zip code usage. Various uses of zip code in business activities are introduced. Some tips as to how to organize a marketing system by using zip codes.

McMullen, Thomas B., *et al*. "Air Quality and Characteristic Community Parameters," *Journal of the Air Pollution Control Association*, XVIII, No. 8 (August, 1968), 545-549.

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Contains data on population and population changes in Standard Metropolitan Statistical Areas.

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One of the whole series enhancing Baltimore, Pittsburgh, Cleveland, Cincinnati, Buffalo, Minneapolis-St. Paul, etc. The literature introduces the Air Quality Act, and discusses the size of the regions chosen, various technical, sociological, geographical, and meteorological factors, and proposes the region under consideration as an Air Quality Control region.

Zip Code Area Data, Individual Income Tax Returns. Washington, D.C.: U.S. Internal Revenue Service, 1966.

Lists the total number of exemptions and the total tax in each three-digit zip code area in the United States. Data broken down into postal regions (first digits). Three-digit maps for each region are included.

E. ODOR MEASUREMENT AND EVALUATION TECHNIQUES

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The design of a facility for the study of odor perception and objectionability thresholds within a large human population is described. The results of tests on nearly 6,000 untrained subjects are reported and analyzed.

American Society for Testing and Materials. Manual on Sensory Testing Methods. Special Technical Publication No. 434. Philadelphia: American Society for Testing and Materials, 1968.

A guide for the technical man who is not an expert in the field, but who is confronted with the need to conduct sensory tests. Includes sections on general requirements, forms of tests, applications, and statistical analyses.

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A collection of six papers on odor sources, measurement, and control together with a discussion.

Byrd, J. F. "Demonstration - Syringe Odor Measurement Technique," Journal of the Air Pollution Control Association, VII, No. 1 (May, 1957).

A review of the rationale and methodology of the syringe odor measurement technique, which utilizes medical type syringes for aliquot withdrawal from stacks and dilution to threshold. Two pages.

City of Portland, Oregon. Bureau of Health. Soiling Index. Information Bulletin No. 9, 1966.

Summary and explanation of soiling index data for Portland are presented. Two pages.

Core, John E. and Arnett, D. E. "The Analysis of C_2 Through C_5 Atmospheric Carbons by Gas Chromatography," Scientific Programmer (November, 1968), pp. 21-22.

An outline of equipment and methodology used to individually monitor at least 14 separate hydrocarbons. 18 pages.

Core, John E., Berg, Neil and Roach, M. D. The Relationship of Degree Days and Other Parameters on Portland's Soiling Index. Portland, Oregon: City of Portland, Bureau of Health, no date.

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Summarizes five-year federally supported project. Concludes that adhesive materials offer an attractive means of measuring particulate concentrations.

Fox, E. A. and Gex, V. E. "Procedures for Measuring Odor Concentration in Air and Gases," Journal of the Air Pollution Control Association, VII, No. 1 (May, 1957).

A detailed procedure for the quantification of odor intensities in terms of dilutions to threshold is outlined. All aspects of the proposed method are covered: sampling and dilution techniques, apparatus, interferences, and calculations. Two pages.

"Gases and Vapors: Methods Giving Quantitative Results in the Field," Industrial Hygiene and Toxicology, Vol. I. Edited by Frank A. Patty. 2nd ed. London: Interscience Publishers, Ltd., 1958.

A discussion of practical problems associated with quantitative assessment of odors in the field, and of the physiological response patterns of human subjects to odors. Five pages.

Hemeon, Wesley, C. L. "Technique and Apparatus for Quantitative Measurement of Odor Emissions," Journal of the Air Pollution Control Association, XVIII, No. 3 (March, 1968).

A description of instruments and techniques developed by the author for the quantitative measurement of odor emissions. Description includes an odor sampling device and a device for controlled dilutions prior to sensory evaluation.

Hillsborough County, Florida. Department of Health. Division of Environmental Engineering. A Comparative Study of Air Pollution - Davis Island, Hillsborough County, Florida, 1968.

A study of a residential area located near major sources of air pollution. Reports include analyses of ambient air data and identifies firms probably responsible for complaints. 48 pages.

Horstman, S.W., Wromble, R. F. and Heller, A. N. "Identification of Community Odor Problems by Use of an Observer Corps," Journal of the Air Pollution Control Association, XV, No. 6 (June, 1965), 261.

To evaluate the major odors affecting a community, approximately 120 high school students recorded odor observations. Simultaneous odor observations were made three times daily for 14 consecutive days each in a fall and spring survey. The observers were tested for olfactory sensitivity. Population characteristics were recorded for analysis of the human variables. These data were analyzed to show the areas most severely affected, the major objectionable odor types, the time when odors were the most frequent, and the associated weather parameters. A critique of the procedures employed and the results of the survey are presented (JAPCA).

Huey, Norman A., et al. Odor Measurement Techniques III. Third Year Final Report. Cincinnati, Ohio: City of Cincinnati, Division of Air Pollution Control and Heating Inspection, 1960.

Describes the development and the field testing of scentometer. 15 pages.

Huey, Norman A., Broering, Louis C. and Gruber, Charles W. Odor Measurement Techniques II. Second Year Final Report. Cincinnati, Ohio: City of Cincinnati, Division of Air Pollution Control and Heating Inspection, 1959.

Report describes development of scentometer and contains recommended procedures for field odor investigations. Correlations are investigated between meteorological variables with complaint frequency. 26 pages.

"It Pays to be Nosy," Marathon World, VI, No. 1 (Winter, 1969).

A short description of a mobil facility developed by Marathon Oil Company for monitoring meteorological and air quality conditions around Marathon installations. One page.

Jenkins, H. N. and Harris, T. O. Interstate Air Pollution Study: Phase II Project Report: IV Odors - Results of Surveys. Cincinnati, Ohio: U.S. Public Health Service, Robert A. Taft Sanitary Engineering Center, 1966.

A survey undertaken to investigate the odor problems in the St. Louis metropolitan area is described. Observations were made at 79 different places, most of which were at fire stations. Odors were classified into ten different types and the type of odor, frequency of detection, data and time of day were reported. Meteorological conditions were also considered.

Nickol, G. B. "Rank Order Method for Evaluating Stack Gases," Journal of the Air Pollution Control Association, VII, No. 1 (May, 1957).

A threshold dilution-based method is presented for the assessment of odor intensities in stack gases. One page.

Odors, the Problem, its Definition and Control. Proceedings of the Mid-Atlantic States Section Semi-Annual Technical Conference, Wilmington, Delaware, November 12, 1965. Pittsburgh, Pennsylvania: Air Pollution Control Association, 1965.

A compilation of papers dealing with odor sources, evaluation, and technical and legislative control. 80 pages.

Stern, A. C. (ed.) *Air Pollution*. 3 vols. 2nd ed. New York: Academic Press, 1968.

The most comprehensive treatment of all phases of air pollution available. Sections of most interest relative to odor problems are Part III, Air Pollution Meteorology, and Part V, Air Quality and Meteorological Measurements.

Stoldt, Stephen H. and Turk, Amos. *Bromination Reactions on Absorbent Surfaces*. Philadelphia, Pennsylvania: State of New Jersey, Department of Health, Air Pollution Control Program, 1968.

An investigation of the mechanisms by which brominated activated carbon removes olefins from the air. Six pages.

Sullivan, D. C., Adams, D. F. and Young, F. A. *Design of an "Odor Perception and Objectionability Threshold" Test Facility*, Vol. II. New York: Pergamon Press, 1968.

Design requirements for facilities to study the thresholds of odor perception and objectionability in large populations are discussed. A mobile facility incorporating these features is described together with the procedures used for administrating tests to subjects.

Sullivan, Ralph J. *Air Pollution Aspects of Odors*. Bethesda, Maryland: Litton Systems, Inc., 1969. Draft copy.

The nature and the sources of odors are introduced. Odor problems and their abatement are discussed. Methods of quantifying the odor problem by means of sensory as well as instrumental investigations are described.

Turk, Amos. "Concentrations of Odorous Vapors in Test Chambers," Basic Principles of Sensory Evaluation. Special Technical Publication No. 433. Philadelphia: American Society for Testing and Materials, 1968.

A presentation of mathematical derivations of expressions which permit prediction of odorant concentrations in terms of chamber volume, time, odor injection rate, and ventilation rate. Five pages.

Turk, Amos and Mehlman, Stanley. "Correlations Between Instrumental and Sensory Characterization of Atmospheric Odors," Correlation of Subjective-Objective Methods in the Study of Odors and Taste. Special Technical Publication No. 440. Philadelphia: American Society for Testing and Materials, 1968.

The sampling and characterization of atmospheric odor sources are discussed. Sensory evaluation of atmospheric odors and correlation with instrumental characterization are included. Nine pages.

Turk, Amos and Wittes, Janet. "The Selection of Judges for Odor Discrimination Panels," Correlation of Subjective-Objective Methods in the Study of Odors and Taste. Special Technical Publication No. 440. Philadelphia: American Society for Testing and Materials, 1968.

Criteria for the screening of candidates for a sensory odor discrimination panel and a screening procedure is outlined which employs three successive tests are discussed. Statistical significance of difference between scores is analyzed. 22 pages.

U.S. Public Health Service, Division of Air Pollution, Kansas City, Kansas, and Kansas City, Missouri. An Odor Survey of the Two Kansas Citys, 1965.

An air resource management program is recommended to deal with regional odor problems. Ambient air odor intensity data are included based on observations by Fire Department personnel at prescribed times. 46 pages.

Wohlers, Henry C. "Recommended Procedure for Measuring Odorous Contaminants in the Field," Journal of the Air Pollution Control Association, XVII (September, 1967), 609-613.

Describes subjective and objective methods for measuring odorous contaminants in the field. Some weaknesses in using human odor perception as a means of measurement are discussed.

F. COMMUNITY PERCEPTION OF ODOR PROBLEMS

Bates, D. V. "Health Costs of Diseases Related to Air Pollution," (Pollution and Our Environment) Conference Background Papers, I. Montreal, Canada, 1967.

It seems very likely that chronic bronchitis is aggravated by urban air pollution and its morbidity increased as a result of this factor. About 20 percent of health costs of chronic bronchitis and emphysema in the population might be partly attributed to the effects of air pollution.

Breslow, L. Air Pollution: Effects Reported by California Residents. Berkeley, California: State of California, Department of Public Health, 1956.

An investigation of the social and psychological aspects of daily living. Characteristics of samples such as sex, age, education, occupation, family income, etc. Major findings: 45 percent of California's adult population are bothered by air pollution. Eye and nasal irritation most frequent. People with chronic respiratory conditions are more sensitive. Most serious and extensive complaints from Los Angeles County.

Crowe, M. Jay. "Toward a 'Definitional Model' of Public Perception of Air Pollution," Journal of the Air Pollution Control Association, XVIII (March, 1968), 154-158.

From a public attitudinal survey conducted in a city in southwest Pennsylvania, different levels or aspects of public perception of air pollution are suggested. This model is analyzed in terms of selected social characteristics, such as education, socio-economic status, and residence.

DeGroot, Ido. "Trends in Public Attitudes Toward Air Pollution," Journal of the Air Pollution Control Association, XII (October, 1962), 679-682.

An attempt to bring together findings related to people's attitudes toward air pollution from a series of studies conducted by or for the U.S. Public Health Service. Trends are noted. Findings are presented in the light of planning for the implementation of air pollution abatement measures and probable public reaction to them. No special reference to the odor problems.

"Gases and Vapors: Methods Giving Quantitative Results in the Field," Industrial Hygiene and Toxicology, Vol. I. Edited by Frank A. Patty. 2nd ed. London: Interscience Publishers, Ltd., 1958.

A discussion of practical problems associated with quantitative assessment of odors in the field, and of the physiological patterns of human subjects to odors. Five pages.

Heller, A. N. Methods of Evaluating Socioeconomic Effects in Air Pollution. (In the Proceedings of the International Conference on Atmospheric Emissions from Sulfate Pulping, Sanibel Island. April 28, 1966.) Ed. by E. R. Hendrickson, Deland, Florida: E. O. Painter Printing Company, no date.

An opinion survey used to study public attitudes toward air pollution is presented. The questionnaire, sample selection and composition, interview situation structure, and survey results are explained.

Hillsborough County, Florida. Department of Health. Division of Environmental Engineering. A Comparative Study of Air Pollution - Davis Island, Hillsborough County, Florida, 1968.

A study of a residential area located near major sources of air pollution. Reports include analyses of ambient air data and identifies firms probably responsible for complaints. 48 pages.

Jennings, Burgess H. Interaction of Man and His Environment. New York: Plenum Press, 1966.

Mainly concerned with environmental health, how man perceives various environmental effects such as air pollution, and how his physiology is affected by them. A cursory survey of man's relation to odor is made. Control methods of malodors are suggested.

Medalia, Nahum Z. Community Perception of Air Quality: An Opinion Survey in Clarkston, Washington. Cincinnati, Ohio: U.S. Public Health Service, 1965.

In a community with a population of 7,000 and located approximately four miles downwind from a pulp mill, a public opinion survey was taken to analyze the environmental stress of air pollution on a sample of household heads and spouses. Two principal attitudinal dimensions — awareness and concern — were investigated.

Randolph, T. G. *Human Ecology and Susceptibility to the Chemical Environment*. Springfield, Illinois: Charles C. Thomas, 1962.

Includes a list of chemical contaminants that produce odors and their subsequent effects on health (case study). Also contained are examples of questionnaires with emphasis on reactions of individuals to chemical odors.

Stalker, W. W. "A Method for Using Air Pollution Measurement and Public Opinion to Establish Ambient Air Quality Standards," *Journal of the Air Pollution Control Association*, XVII (March, 1967), 142-147.

Air quality was comprehensively evaluated by means of sampling at 21 locations over metropolitan Birmingham during a period of one year. Thousands of integrated samples of three common atmospheric gaseous pollutants and two common particulate pollutants were collected and analyzed. The relationships between ambient air quality and neighborhood opinion effects on health and property are evaluated statistically.

U.S. Public Health Service. *People and Air Pollution: A Study of Attitudes in Buffalo, New York (An Interdepartmental Report)*, 1962.

Examines questions relative to the levels of awareness and concern about air pollution. Hypotheses relating public attitudes to air pollution and certain social factors are tested.

Williams, J. D. *Interstate Air Pollution Study: Phase II Project Report: VI Effects of Air Pollution*. Cincinnati, Ohio: U.S. Public Health Service, Robert A. Taft Sanitary Engineering Center, 1966.

Report of a survey in the St. Louis metropolitan area. Sections are devoted to the following: (1) methods available for setting air quality goals, (2) deleterious effects of sulphur oxides, H_2S, CO, oxidants and particulate matter, (3) odors, (4) effects on asthma sufferers, (5) aeroallergens, (6) deterioration of steel, nylon, and cotton fabrics, (7) vegetation damage, (8) effects of air pollution on property values, (9) public opinion survey, (10) summary of effects on human health, and (11) summary of economic effects.

Zotterman, Y. (ed.) Olfaction and Taste. Vol. I. New York: Pergamon Press, 1963.

A collection of research papers dealing with physiological response mechanisms of man and animals to tastes and odors. Orientation is highly theoretical.

G. ODOR ABATEMENT AND CONTROL

American Society for Testing and Materials. Symposium on Odor. Special Technical Publication No. 164. Philadelphia: American Society for Testing and Materials, 1954.

A collection of six papers on odor sources, measurement, and control together with a discussion.

Bay Area Air Pollution Control Districts. Air Pollution and the San Francisco Bay Area, 1969.

A general discussion of air pollution. Provides information on different kinds of smogs, various effects of air pollution, and statistics on counties in and around San Francisco area. Meteorological and geographical explanation of smog in the Bay Area is presented. Bay Area Air Pollution Control District and its functions are described.

City of Cincinnati, Ohio. Division of Air Pollution Control and Heating Inspection. Ordinance Regulations Pertaining to Air Pollution Control and Heating, Mechanical Ventilation and Refrigeration of the City of Cincinnati, 1965.

A basic air pollution regulation. Odors are in violation if found to cause injury, annoyance, or detriment to the public or to any person. 25 pages.

City of Kansas City, Kansas. Kansas City, Kansas Air Pollution Ordinance: 1966. Ordinance No. 45834.

Odors are covered only by implication under nuisance statute.

City of Kansas City, Missouri. Committee Substitute for Ordinance No. 36539 - An Ordinance, 1969.

Proposed air pollution ordinance to bring City statute into conformity with State regulations. Odors handled under public nuisance section.

City of Philadelphia, Pennsylvania. Department of Public Health. Air Management Services. *Air Pollution Code*.

Contains the sections of the General Ordinances of the City of Philadelphia dealing with air pollution. Delineates powers of City agencies relative to air pollution. Includes general nuisance statute relative to odors. 12 pages.

__________. *Air Pollution from Diesel Powered Vehicles in Philadelphia*, 1965.

A discussion of the major pollutants of diesel engines. Recommends citations for diesel powered vehicles emitting excessive odors. 11 pages.

__________. *Air Pollution from Fuel Combustion Processes in Philadelphia*, 1966.

An analysis of major categories of combustion processes in terms of air pollution problems. Recommendations are made regarding control measures.

__________. *Air Pollution Problems from Refuse Disposal Operations in Philadelphia and the Delaware Valley*, 1969.

A discussion of the causes of air pollution from refuse combustion and the measures which may be taken to reduce emission, including odor control at incinerators. Ten pages.

__________. *Amendments of Regulations of the Air Pollution Control Board, City of Philadelphia, Relating to Control of Incinerators*, 1969.

The emissions standards for incinerators. Includes a provision that gases from the primary combustion chamber shall be maintained for a sufficient length of time at and as a temperature not to be less than 1400°F in order to prevent odorant emission.

__________. *Regulations of the Air Pollution Control Board*, Revised 1966.

Air pollution regulations for Philadelphia. Odors are treated under the nuisance statute. 16 pages.

City of Portland, Oregon. Bureau of Health. Incinerators. Information Bulletin No. 11. 2nd Revision, 1967.

A summary of City's Air Quality Control Code provisions relative to incinerators. One page.

Columbia-Willamette Air Pollution Authority. Open Outdoor Fires. Information Bulletin No. 3, 1968.

A basic regulation on controlling open outdoor fires. Includes ban on any open fires which generally cause obnoxious odor. Four pages.

__________. Prohibited Emissions. Information Bulletin No. 2, 1968.

Lists emission standards for visible emissions, particulates and odors. Odor standards specify maximum intensities in terms of dilutions to threshold. Two pages.

__________. Rules II, 1969. Draft copy.

A basic regulatory document. Includes odor provisions based on both nuisance and scentometer criteria. Scentometer standards vary with land use.

__________. Statutory Authority and Powers of the Columbia-Willamette Air Pollution Authority. Appendix A - Information Bulletin No. 1, 1968.

Outlines the scope, powers, organization, and financing of the agency. Seven pages.

Erie County, New York. Department of Health. Erie County Sanitary Code, Article XIV, Air Pollution Control, 1969.

A basic air pollution law that treats odors only under nuisance provisions. 49 pages.

Faith, W. L. "Odor Control in Cattle Feed Yards," Journal of the Air Pollution Control Association, XIV (November, 1964), 459-461.

A discussion of types of odor problems from cattle feed yards, some odor control methods, and the state of cattle-feeding industry in general.

Fink, R. H. "A Management Approach to Odor Control," Journal of the Air Pollution Control Association, VII, No. 1 (May, 1957).

A management methodology for dealing with odors is outlined. The approach entails source identification followed by an aggressive and persistent control program. Two pages.

Gruber, Charles A. Odor Pollution From the Official's Viewpoint. Cincinnati, Ohio: City of Cincinnati, Division of Air Pollution Control and Heating Inspection, no date.

Discusses the unique problems associated with odor abatement, together with case histories of specific problems. An approach to odor quality measurement is proposed. Ten pages.

Gruber, Charles W. and Jutze, G. A. Teamwork in Air Pollution Control. Cincinnati, Ohio: City of Cincinnati, Division of Air Pollution Control and Heating Inspection, 1960.

Describes the program by which City of Cincinnati provides air pollution control services to neighboring communities on a contract basis. Two pages.

Hatchard, R. E. Intercommunity Cooperation in Air Resources Management. Portland, Oregon: City of Portland, Bureau of Health, 1966.

Discusses the factors promoting development of regionalism in air quality management, together with an outline of the growth of a regional air pollution agency in the Portland area. Seven pages.

Hillsborough County, Florida. Department of Health. Division of Environmental Engineering. Hillsborough County Pollution Control Commission - Chapter 67-1504, House Bill No. 2127.

Presents the State of Florida statute creating the Hillsborough County Pollution Control Commission.

__________. Hillsborough County Pollution Control Commission - Rules and Regulations.

Contains technical and administrative regulations covering air and water pollution. No mention of odors. 34 pages.

__________. Hillsborough County's Program for Clean Air, no date.

Outlines agency activities including emissions inventories, ambient air quality measures, and meteorological studies. Eight pages.

__________. Report of Health Department Services, 1969.

Discusses major pollution problems and actions taken to achieve abatement. 26 pages.

Kollatz, Charles W. Annual Report of the Erie County Health Department, Division of Air Pollution Control, Erie, New York: Erie County Department of Health, 1968.

Public information document notes 48 odor complaints in the year 1968 out of a total of 282 complaints. 11 pages.

Lemkuhl, Richard B. Intercommunity Air Pollution Control Program Activities for 1968. Cincinnati, Ohio: City of Cincinnati, Division of Air Pollution Control and Heating Inspection, 1968.

An annual summary of activities of Cincinnati air pollution agency program to provide service to neighboring communities on a contract basis. Brief description of specific odor abatement cases. Eight pages.

MacKenzie, V. G. "Future Outlooks for the Development and Application of Air Quality Standards," Journal of the Air Pollution Control Association, XIV (January, 1964), 19-22.

A discussion of the types of information needed for air quality standard guides: effects of pollutants on mortality, acute illness, production of chronic diseases, impairment of important physiological functions, the production of sensory irritations (including odors), damage to vegetation and property, and community dissatisfaction.

Magill, Paul I. (ed.) Air Pollution Handbook. New York: McGraw-Hill Book Company, Inc., 1956.

A single volume introduction to air pollution, its causes, effects, and methods of control.

Manatee County, Florida. Department of Health. Manatee County Air and Water Pollution Control Code.

A basic code covering responsibilities of Health Department in air pollution.

Odors, the Problem, its Definition and Control. Proceedings of the Mid-Atlantic States Section Semi-Annual Technical Conference, Wilmington, Delaware, November 12, 1965. Pittsburgh, Pennsylvania: Air Pollution Control Association, 1965.

A compilation of papers dealing with odor sources, evaluation, and technical and legislative control. 80 pages.

Oregon State Sanitary Authority. Hot Mix Asphalt Plants. Information Bulletin No. 3, 1968.

Contains emission regulations for hot mix asphalt plants. Criteria are based on production and location. No emission standards are set for odors. Two pages.

Roach, Michael D. and Arnett, David E. Computer Application in Air Resources Management. Portland, Oregon: City of Portland, Bureau of Health, no date.

Use of computers is described for data storage and statistical analyses of various types of air pollution data compiled within the agency. 19 pages.

Sableski, J. J. "The Federal Air Pollution Control Program as it Relates to the Kraft Pulping Industry," Journal of the Technical Association of Pulp and Paper Industries, L (August, 1967), 35A-39A.

The federal air pollution program as it relates to the kraft pulping industry, with particular emphasis on the odorous character of the industry's atmospheric emissions, is described in terms of four individual federal activities: (1) research, (2) grants-in-aid, (3) technical assistance, and (4) abatement actions. (Author's Abs.)

Stanley, William J. and Cranshaw, David D. "The Use of a Computer-Based Total Management Information System to Support an Air Resource Management Program," Journal of the Air Pollution Control Association, XVIII, No. 3 (March, 1968), 158-159.

The role of computer technology in air resource management is discussed, including development of an early warning system for the prediction of hazardous levels of pollution.

State of New Jersey, Department of Health. Air Pollution Control Program. New Jersey Air Pollution Control Code.

Contains detailed regulations, with separate chapters covering major sources of pollution. Odors are handled under general provision banning air pollution.

__________. New Jersey Air Pollution Control Laws - General Provisions of 1954 Act as Amended.

Presents the state law establishing the powers of the State Department of Health relative to air pollution.

Stern, A. C. (ed.) *Air Pollution*. 3 vols. 2nd ed. New York: Academic Press, 1968.

The most comprehensive treatment of all phases of air pollution available. Sections of most interest relative to odor problems are Part III, Air Pollution Meteorology, and Part V, Air Quality and Meteorological Measurements.

__________. "Emission Standards in Air Pollution," *American Journal of Public Health*, LV (July, 1965), 1075-1081.

A discussion of emission standards to be employed in dealing with air pollution is presented. It is urged that standards be developed for real situations which relate both single and multiple sources to community's air quality standards (gas and fine particles).

__________. "Implications of the Air Quality Act of 1967," *Transcript of the New York Academy of Science*, XXX (April, 1968), 759-765.

The Air Quality Act of 1967 is assessed. It incorporates the body of federal air pollution legislation that had developed from 1955 through 1966, setting a firm basis for the outgoing programs of research, training, technical, and financial assistances, and interstate and motor vehicle pollution abatement. It establishes a Presidential Air Quality Advisory Board. The implications of the requirements and limitations of the Act are reviewed. (Chem. Abs.)

__________. "Summary of the Conference on Odor Control," *Journal of the Air Pollution Control Association*, VII, No. 1 (May, 1957).

A discussion of the nature of odor problems in general, and of conditions complicating the problem in Cincinnati. A four-point program for odor abatement in the area is proposed which emphasizes political and financial aspects of the abatement process. Two pages.

Strauss, W. "The Development of a Condenser for Odor Control from Dry Rendering Plants," *Journal of the Air Pollution Control Association*, XIV (October, 1964), 424-427.

Contains a brief comment on odor from the rendering industry and a discussion of the local control requirements around the Los Angeles area.

Summer, W. Methods of Air Deodorization. Amsterdam: Elsevier, 1963.

A comprehensive introduction to odors, including theories of olfaction, properties of odorants, meteorology, and detailed discussions of each of the common methods of deodorization.

Teller, A. J. "Odor Abatement in the Rendering and Allied Industries," Journal of the Air Pollution Control Association, XIII (April, 1963), 148-150.

Discusses problems created by odor and profitability of odor abatement. Describes some of the sources of air pollution in rendering and allied industries. Provides suggestions as to the odor control methods.

Thring, Meredith W. Air Pollution. London: Butterworth Scientific Publication, 1957.

Treats air pollution in general, including various sources of air pollution, measurement, effects on health, and geographical factors. Discusses elimination of pollution originating from sources such as domestic heating, motor vehicle exhausts, and cement manufacture. Noxious odors are discussed in connection with processes such as food preparation, tanning, and fish meal preparation.

Turk, Amos. "Odor Control," Kirk-Othmer Encyclopedia of Chemical Technology, 2nd ed., XIV (1967), 170-178.

A review of community air pollution problems and methods of odor control includes: ventilation or dispersal, adsorption, air oxidations, conversions, washing and scrubbing, irradiation, use of quaternary ammonium compounds, and counteracting and masking agents.

U.S. Congress. Air Quality Act of 1967. Public Law 90-148, S780, 1967.

Amendment to Clean Air Act authorizing, among other things, establishment of air quality standards. 23 pages.

U.S. Public Health Service. *Compilation of Selected Air Pollution Emission Control Regulations and Ordinances*. Rev. 1968. PHS Publ. 999-AP-43.

A presentation of air pollution ordinances including odor emission control provisions from Chicago, Cleveland, and St. Louis air pollution codes. 146 pages.

__________. *Digest of State Air Pollution Laws*, 1966. PHS Publ. 711.

A compilation of all state air pollution laws is presented verbatim. 556 pages.

__________. *Kansas City, Kansas - Kansas City, Missouri Air Pollution Abatement Activity. Phase II - Pre-Conference Investigations*, 1968.

A summary of local air pollution abatement activities, in terms of ambient air quality, climatological studies, and pollutant emissions. No special attention given to odors. 180 pages.

__________. *Progress in the Prevention and Control of Air Pollution*. (First Report of the Secretary of Health, Education and Welfare to the U.S. Congress, pursuant to Public Law 90-148, *The Air Quality Act of 1967*), 1968.

A summary of progress in air pollution control in terms of administration, abatement, and research. 85 pages.

__________. *Status Report for the Kansas City Metropolitan Interstate Air Quality Control Region*, 1969.

An outline of the organization, staffing, budget allocations, and accomplishments of air pollution agencies in the Kansas City region. Includes data on ambient air quality, emissions, and meteorology. 55 pages.

U.S. Public Health Service. National Air Pollution Control Administration. 1968. Report for Consultation on the San Francisco Bay Area Air Quality Control Program, 1968.

One of the whole series enhancing Baltimore, Pittsburgh, Cleveland, Cincinnati, Buffalo, Minneapolis-St. Paul, etc. The literature introduces the Air Quality Act, and discusses the size of the regions chosen, various technical, sociological, geographical, and meteorological factors, and proposes the region under consideration as an Air Quality Control region.

__________. State of Pennsylvania and Philadelphia Odor Complaints, 1969.

A tabulation of odor complaints in the Philadelphia area for 1967-68. Complaints are described in terms of postal zone, odor type, and name of source.

H. GENERAL INFORMATION ON THE ODOR PROBLEM

City of Philadelphia, Pennsylvania. Department of Public Health. *The Air You Breathe - Air Pollution and its Control in Philadelphia*, no date.

An introduction to causes and the nature of air pollution, and a description of Philadelphia's program to control air pollution.

Faith, W. L. "Air Pollution Research - Reflection and Projection," *Journal of the Air Pollution Control Association*, XIV (September, 1964), 367-370.

Contains comments on the odor problem and the various angles from which it can be attacked.

Gruber, Charles A. *Air Pollution Control in Cincinnati*. Cincinnati, Ohio: City of Cincinnati, Division of Air Pollution Control and Heating Inspection, 1968.

Public information booklet describes sources of local air pollution and activities of agency in controlling air pollution. 12 pages.

Hillsborough County, Florida. Department of Health. Division of Environmental Engineering. *Air Pollution: The Hidden Danger*, no date.

Public information booklet introduces concepts of oxygen and carbon dioxide balances and the potential effects of energy generation, pesticides, etc. Six pages.

__________. *The Facts About Air Pollution*, 1969.

Public information booklet outlining the causes of air pollution, and the effects of major pollutants. Eight pages.

Lewis, Howard R. *With Every Breath You Take*. New York: Crown Publishers, Inc., 1965.

A general non-technical discussion of air pollution. Fairly extensive treatment of the odor problem. Different types of odors and odor sources, effects of odor on local population, and types of odor-controlling methods are discussed. Includes a brief bibliography on the odor problem.

Middleton, John T. The Air Quality Act of 1967 - A Challenge to the Scientist. U.S. Public Health Service, 1968. (Presented to The Chemical Society of Washington, Washington, D.C., January 11, 1968).

The government laboratories working jointly with the academic community and private industry under the Air Quality Act of 1967 will make possible a greatly accelerated program of research in all our areas of ignorance.

U.S. Public Health Service. National Air Pollution Control Administration. Air Pollution Publications, Selected Bibliography with Abstracts 1966-1968. PHS Publ. 979.

Contains abstracts of approximately 900 federally sponsored investigations of air pollution-related topics. 144 pages.

U.S. Public Health Service. Sources of Air Pollution and Their Control, 1966. PHS Publ. 1548.

Public information booklet discusses major sources on common pollutants, and briefly lists means of abatement. 16 pages.